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Ogata et al.

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(54) **LIGHT-EMITTING DEVICE AND LIGHTING APPARATUS USING THE SAME**

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(30) **Foreign Application Priority Data**

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H01L 23/522	(2006.01)
H01L 41/047	(2006.01)
H05K 3/28	(2006.01)
F21S 8/02	(2006.01)
F21Y 101/02	(2006.01)
F21Y 105/00	(2006.01)
H05K 1/02	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 23/5228*** (2013.01); ***H01L 41/047*** (2013.01); ***H05K 3/284*** (2013.01); *F21S 8/026* (2013.01); *F21Y 2101/02* (2013.01); *F21Y 2105/001* (2013.01); *H05K 1/0296* (2013.01); *H05K 2201/10106* (2013.01)

(58) **Field of Classification Search**

CPC H01L 23/5228; H01L 41/047
USPC 257/692, 779, 784; 438/612–617
See application file for complete search history.

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(57) **ABSTRACT**

A light-emitting device includes a substrate, first LEDs and second LEDs mounted on the substrate, multiple wirings separately formed on the substrate, and a conductive member for connecting adjacent two wirings in multiple wirings for establishing series connection, parallel connection, or a combination of series and parallel connections of the first LEDs and the second LEDs. This achieves the light-emitting device that can support multiple different specifications, using a single type of substrate.

19 Claims, 17 Drawing Sheets

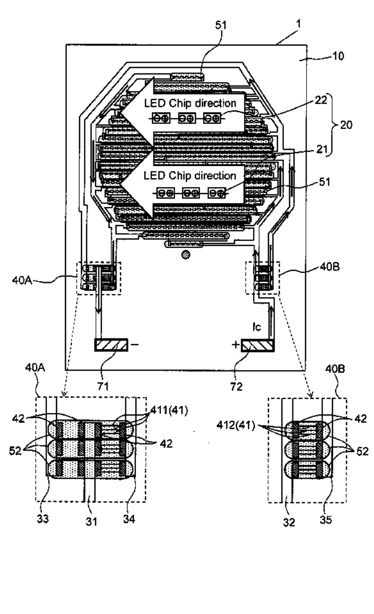


FIG. 1A

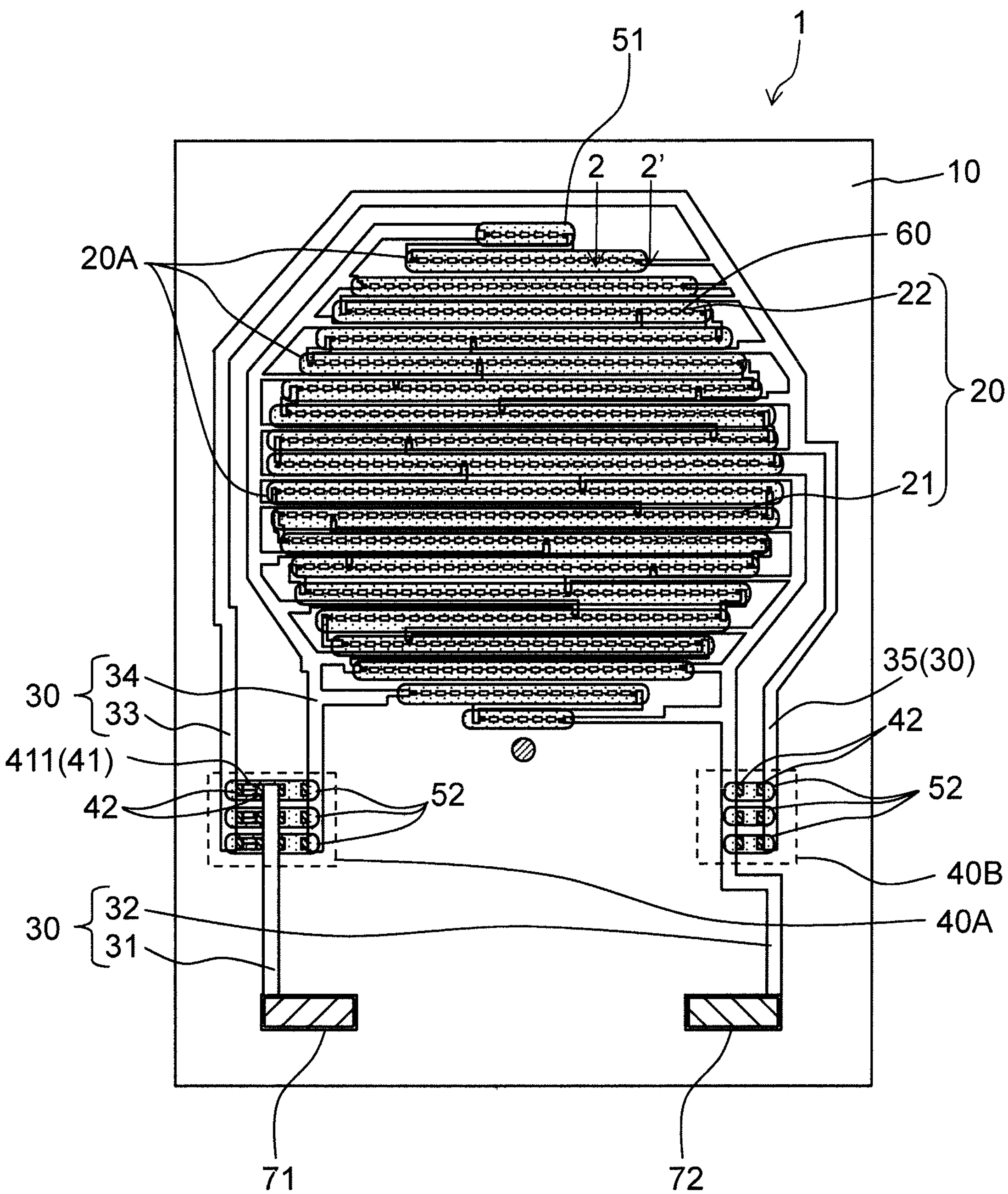

1
51
2
2'
10
20A
60
22
20
21
30
34
33
35(30)
42
411(41)
42
52
52
40B
30
32
31
40A
71
72

FIG. 1B

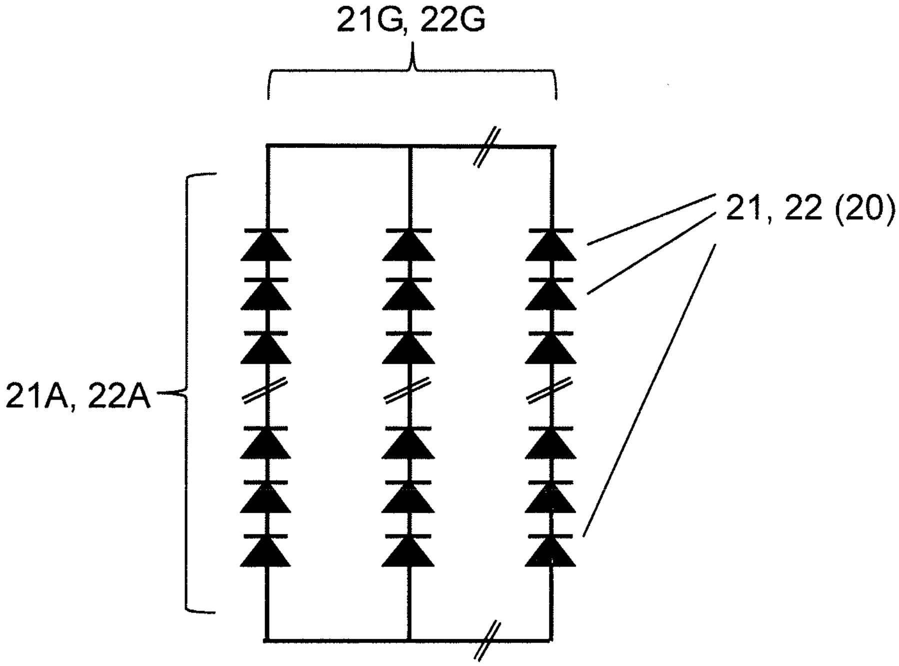


FIG. 2

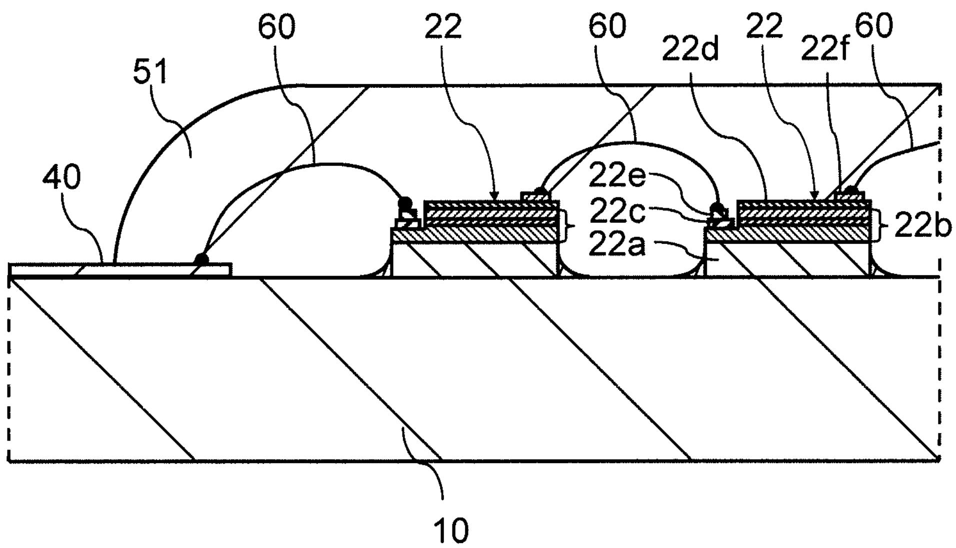
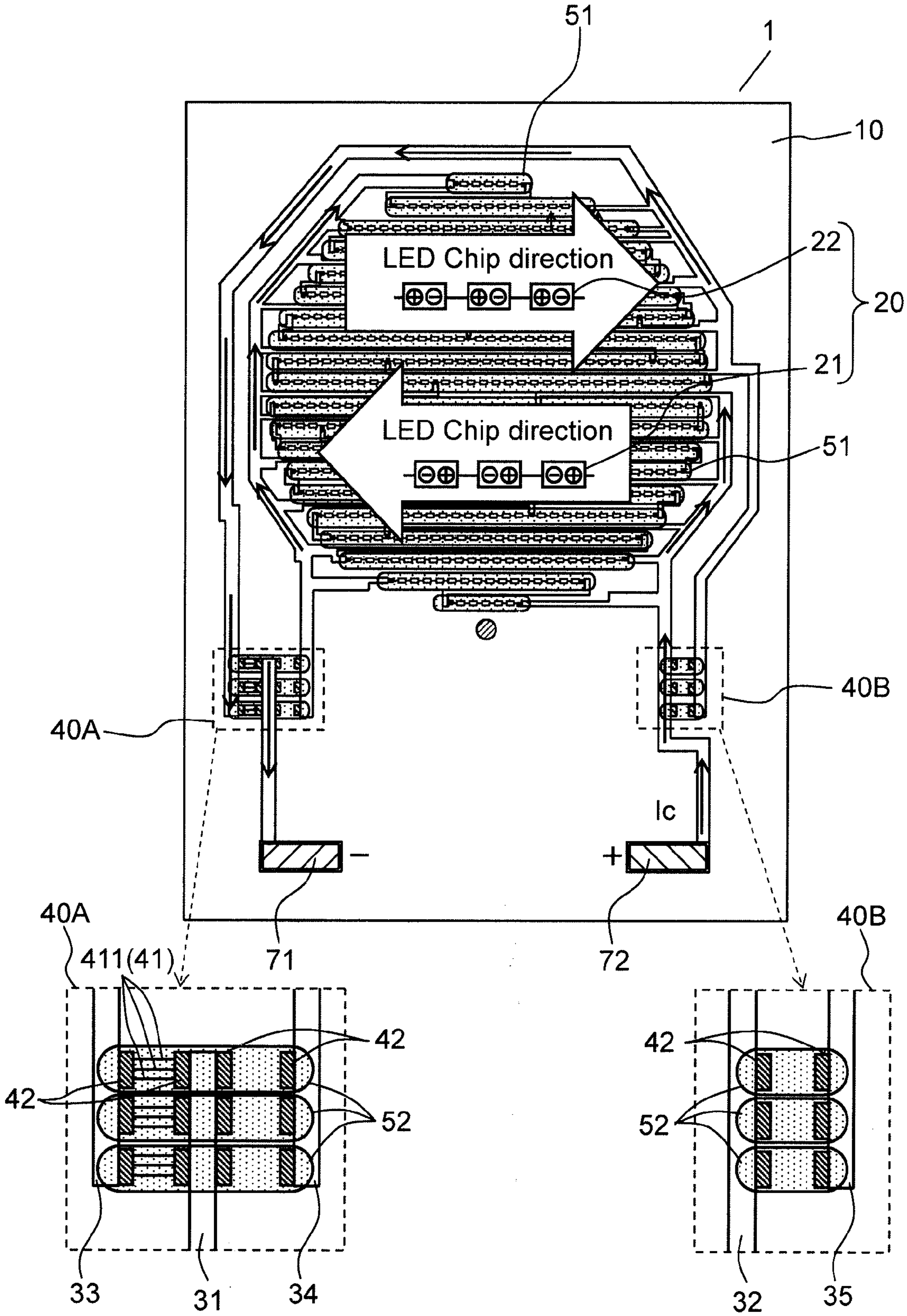


FIG. 3



51
1
10
LED Chip direction
22
20
21
LED Chip direction
51
40B
40A
Ic
−
+
71
72
40A
411(41)
42
42
52
33
31
34
40B
42
52
32
35

FIG. 4A

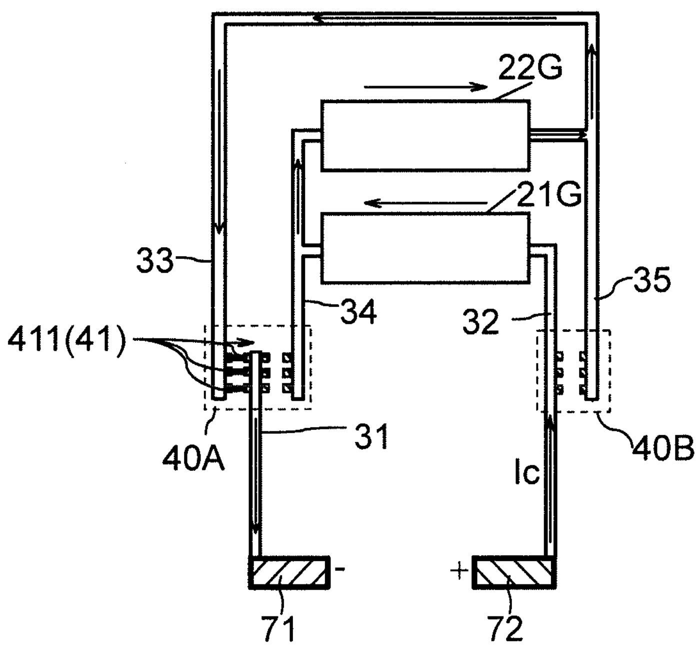


FIG. 4B

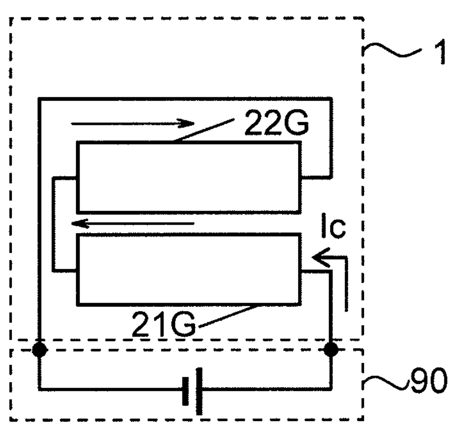


FIG. 5

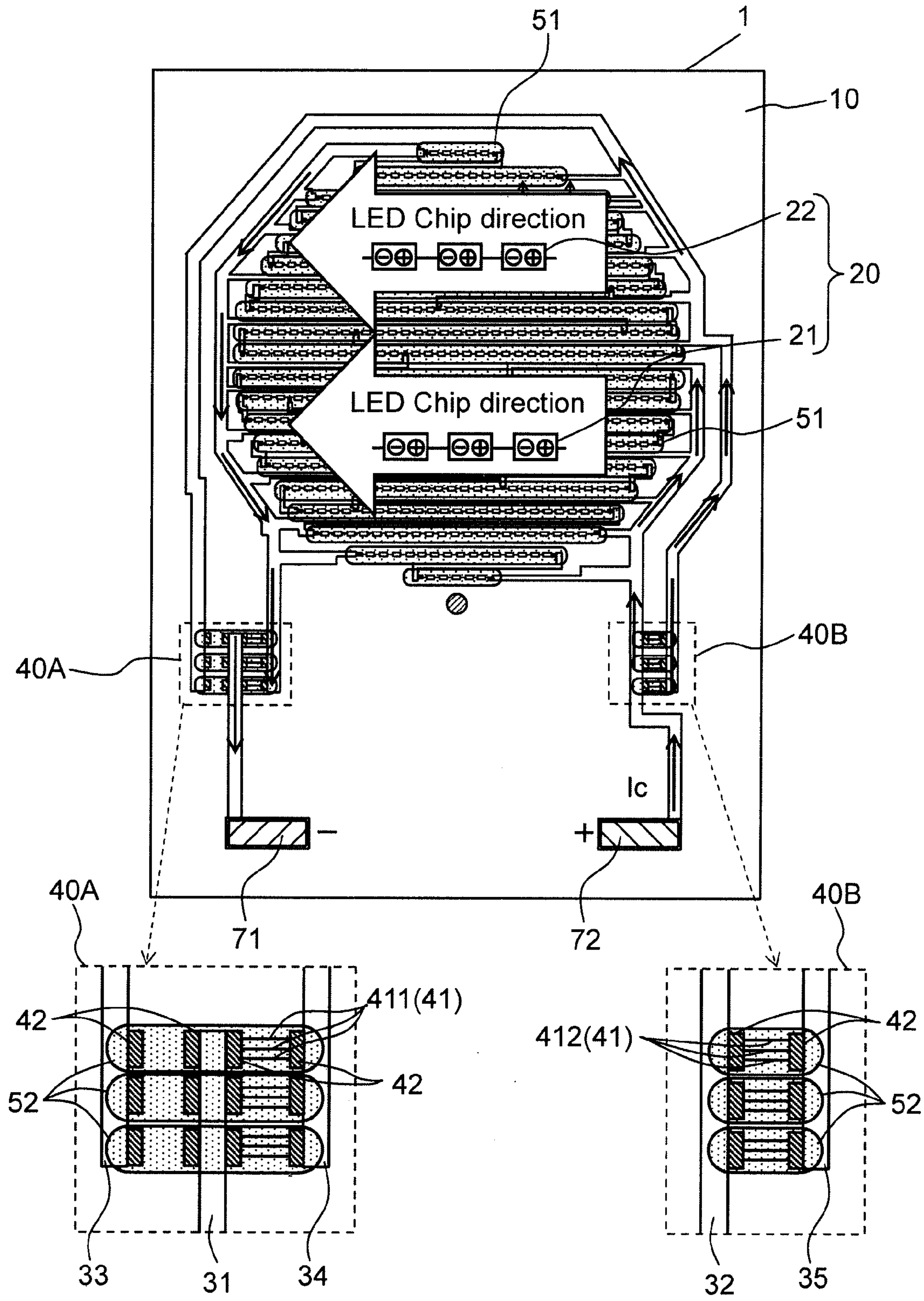

51
1
10
LED Chip direction
22
20
21
LED Chip direction
51
40A
40B
Ic
−
+
71
72
40A
40B
42
411(41)
42
52
412(41)
42
52
33
31
34
32
35

FIG. 6A

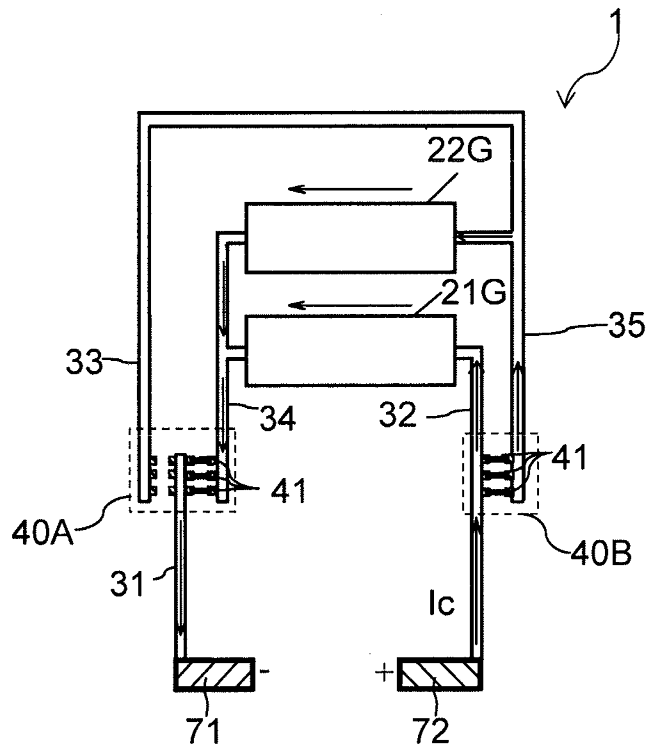


FIG. 6B

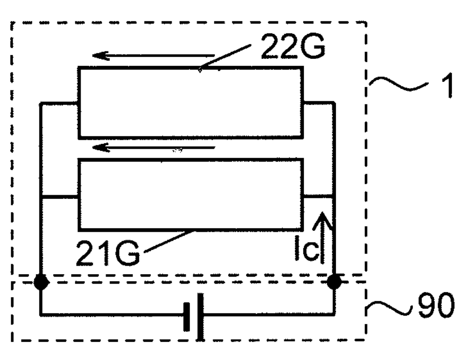


FIG. 7

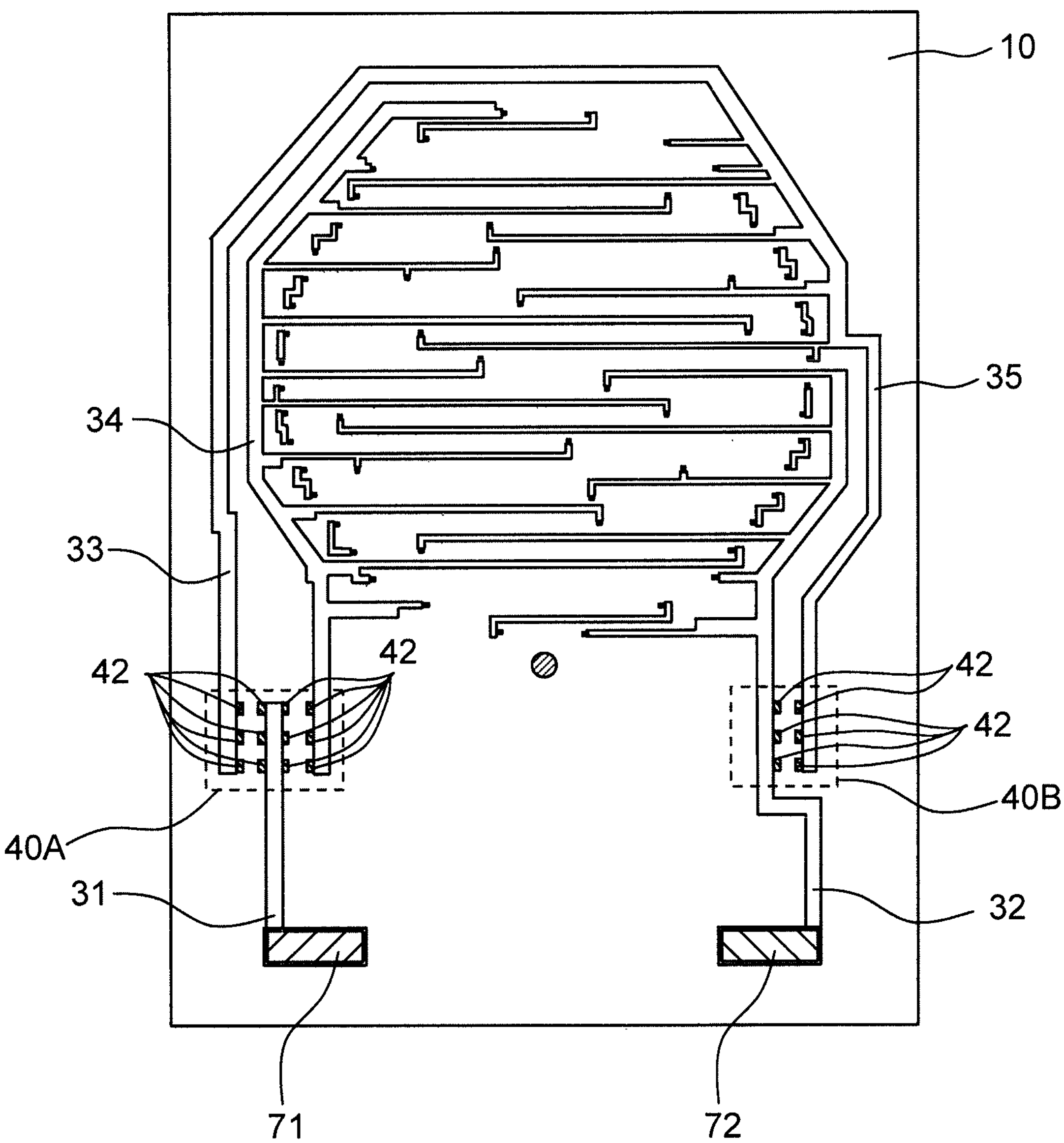


FIG. 8

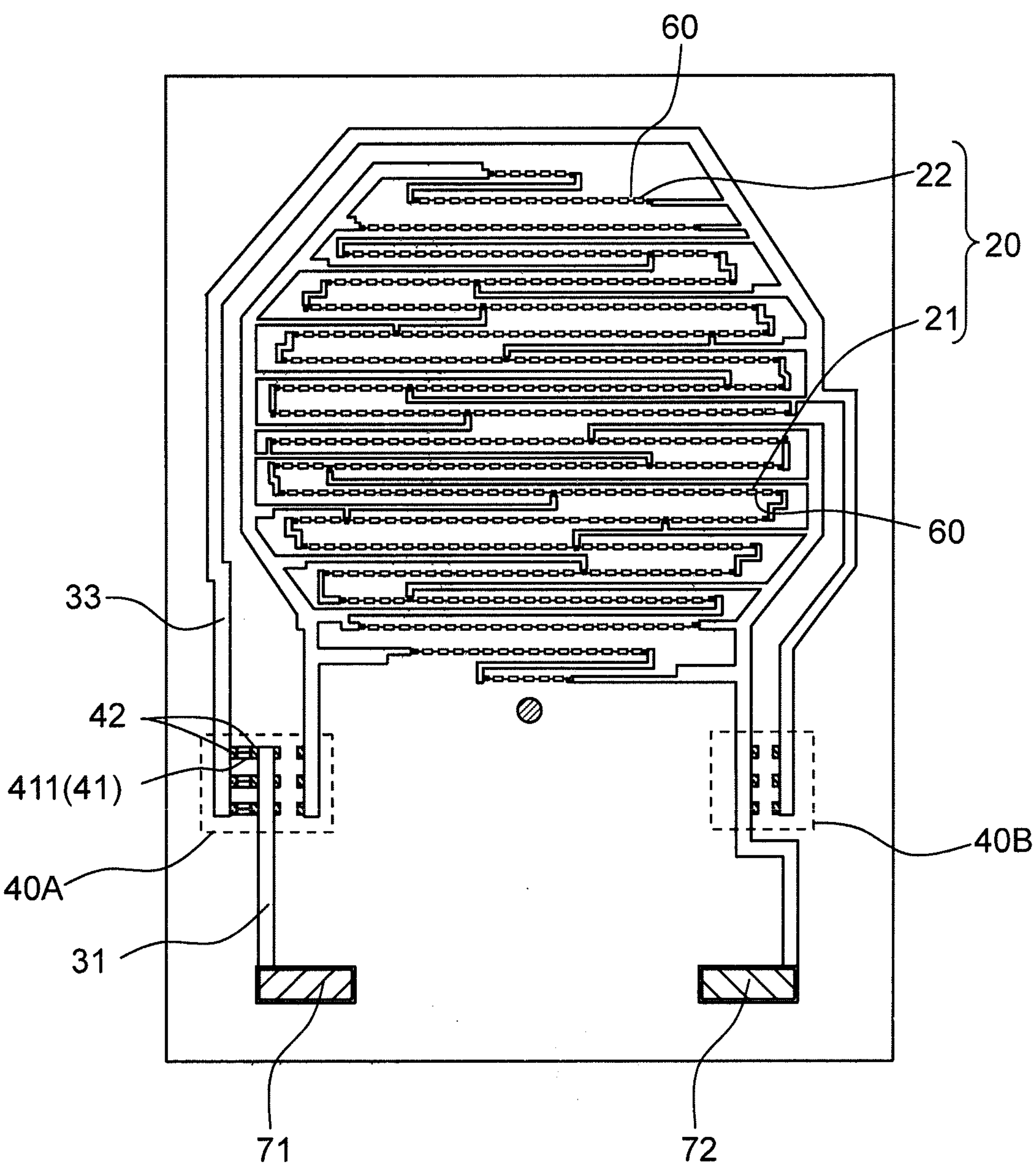


FIG. 9

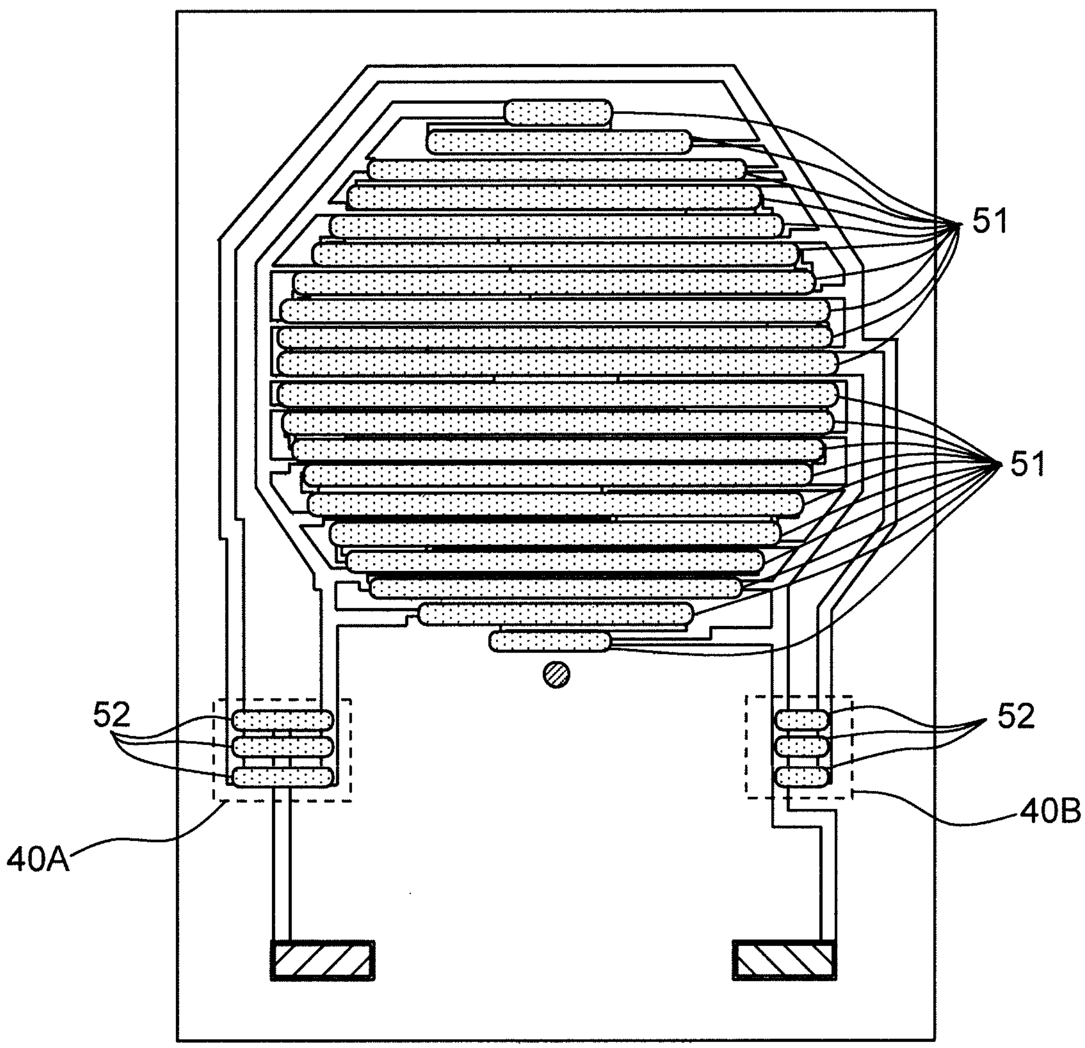


FIG. 10A

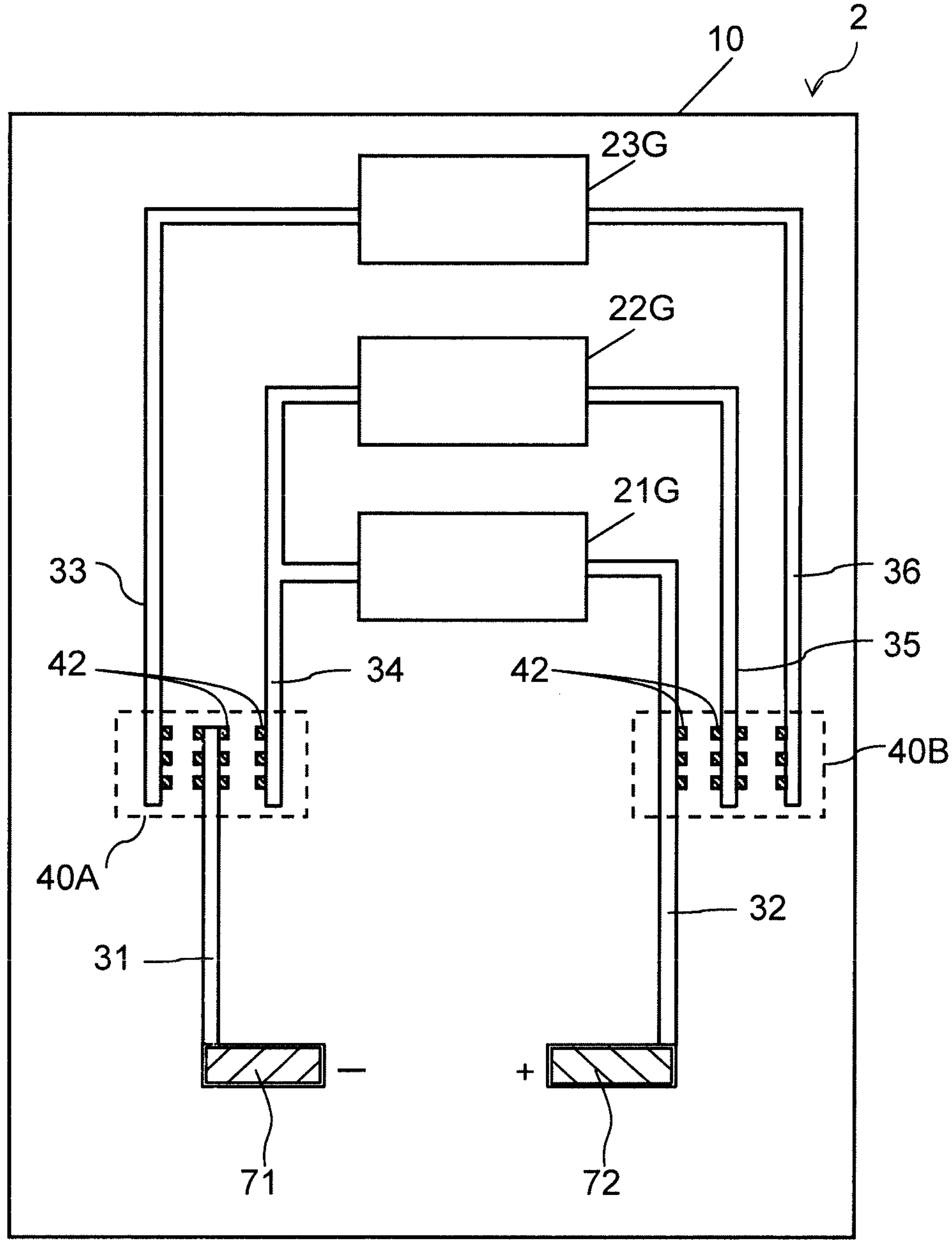


FIG. 10B

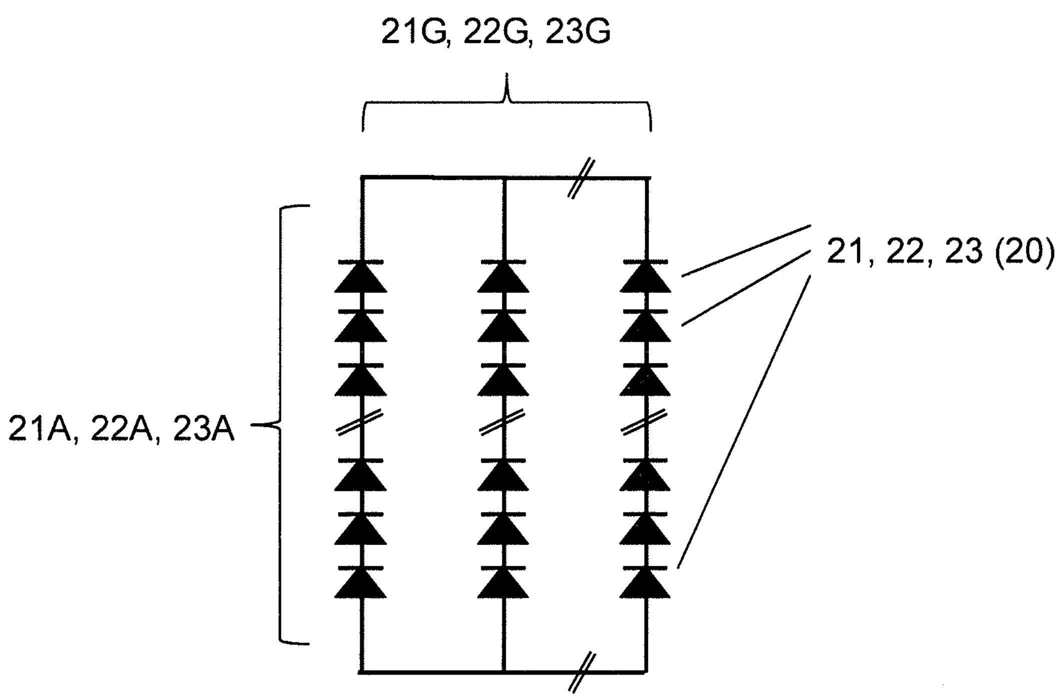


FIG. 11A

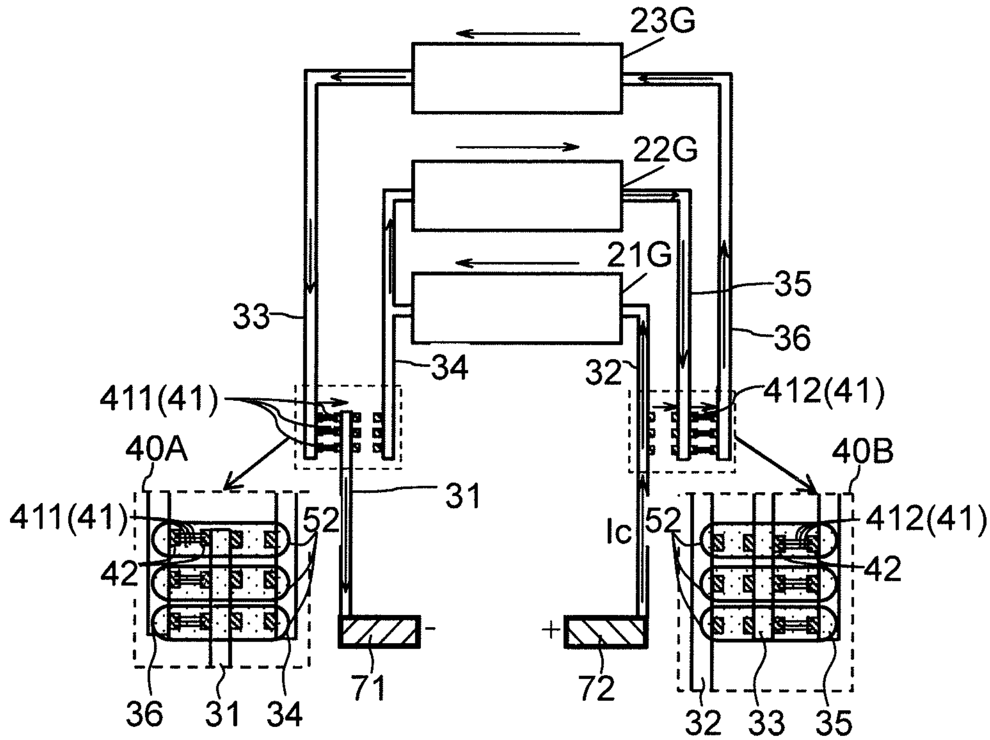


FIG. 11B

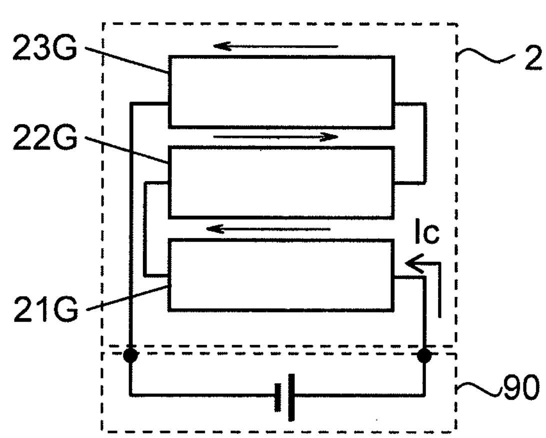


FIG. 12A

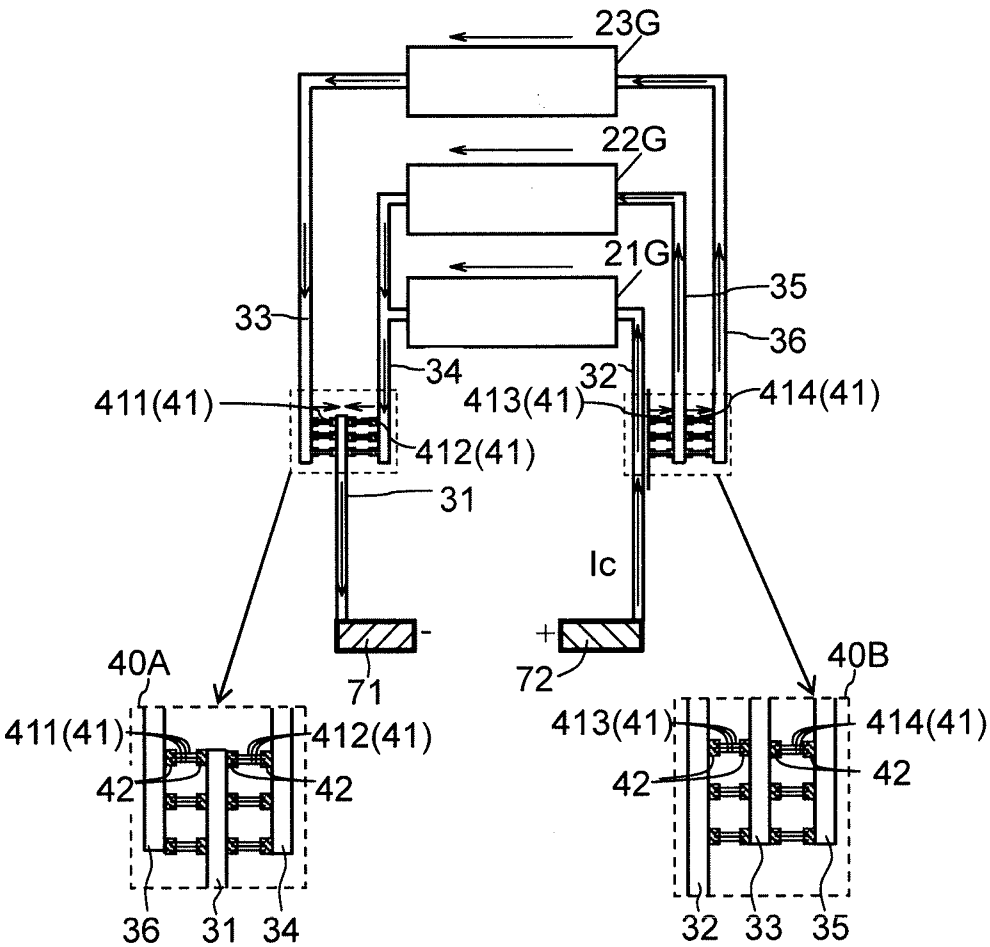


FIG. 12B

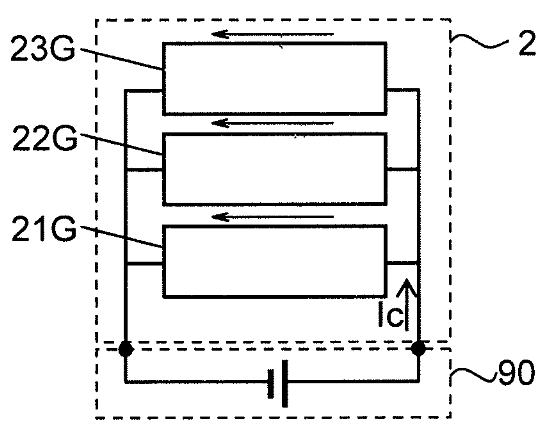


FIG. 13

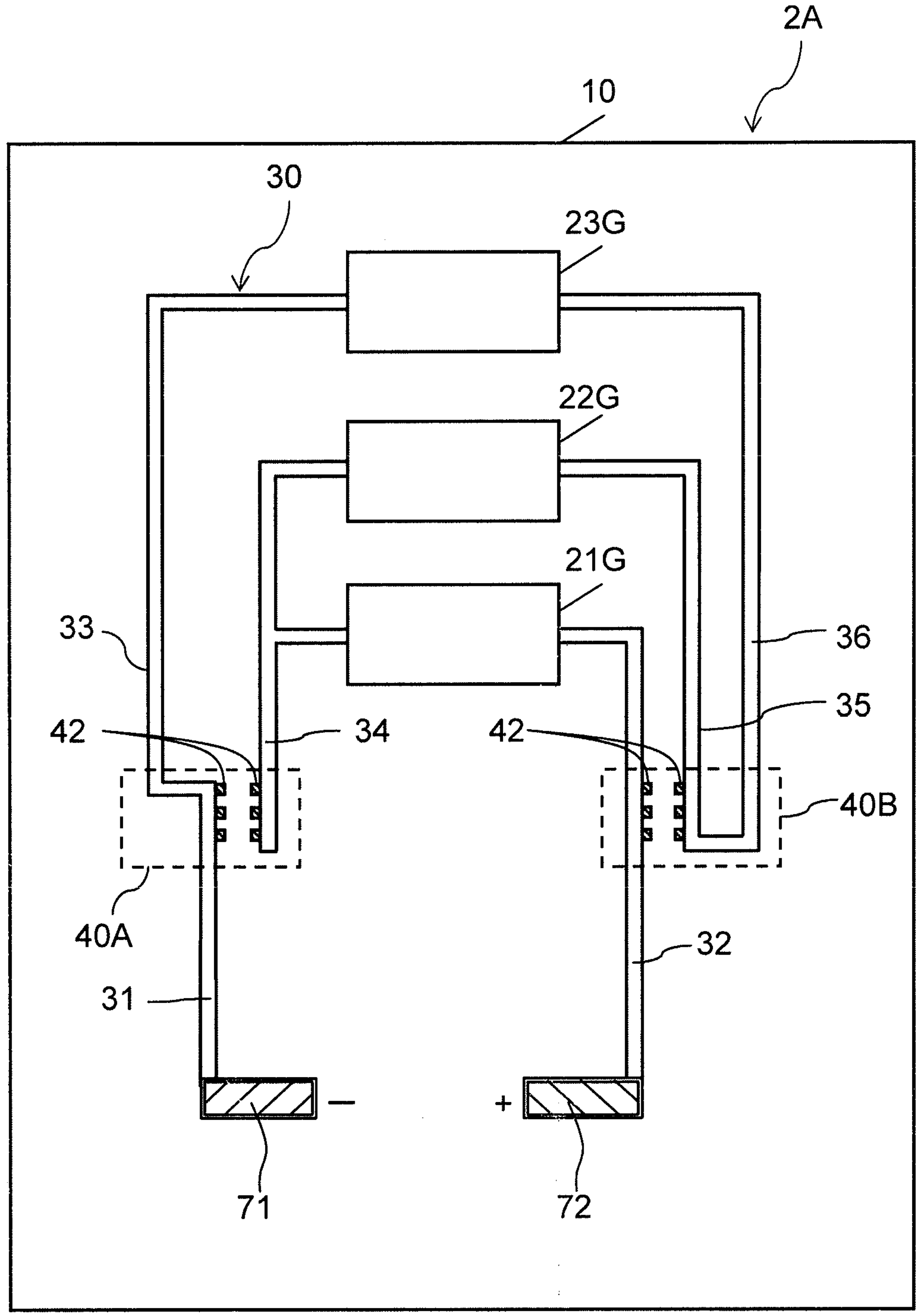


FIG. 14

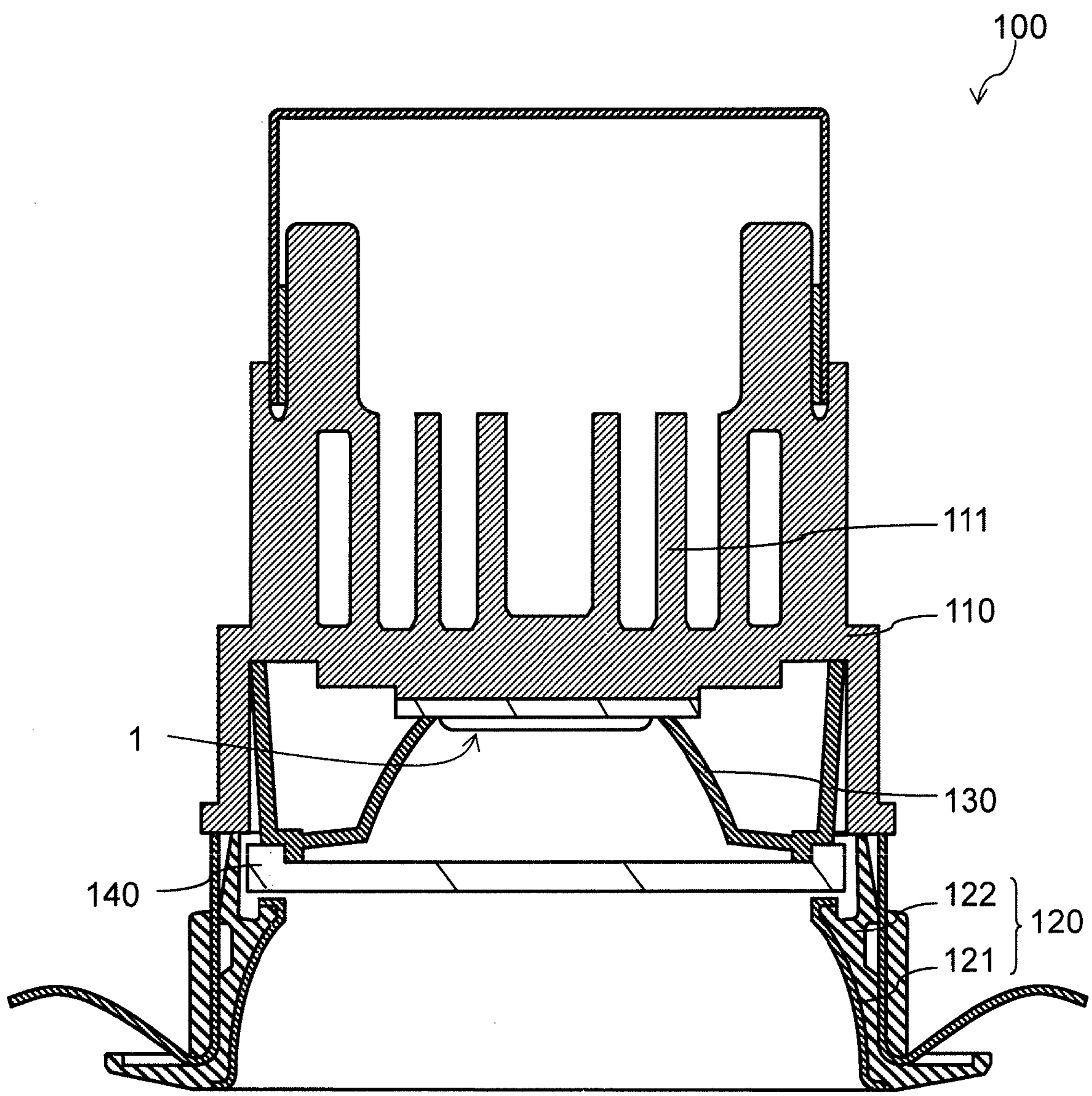
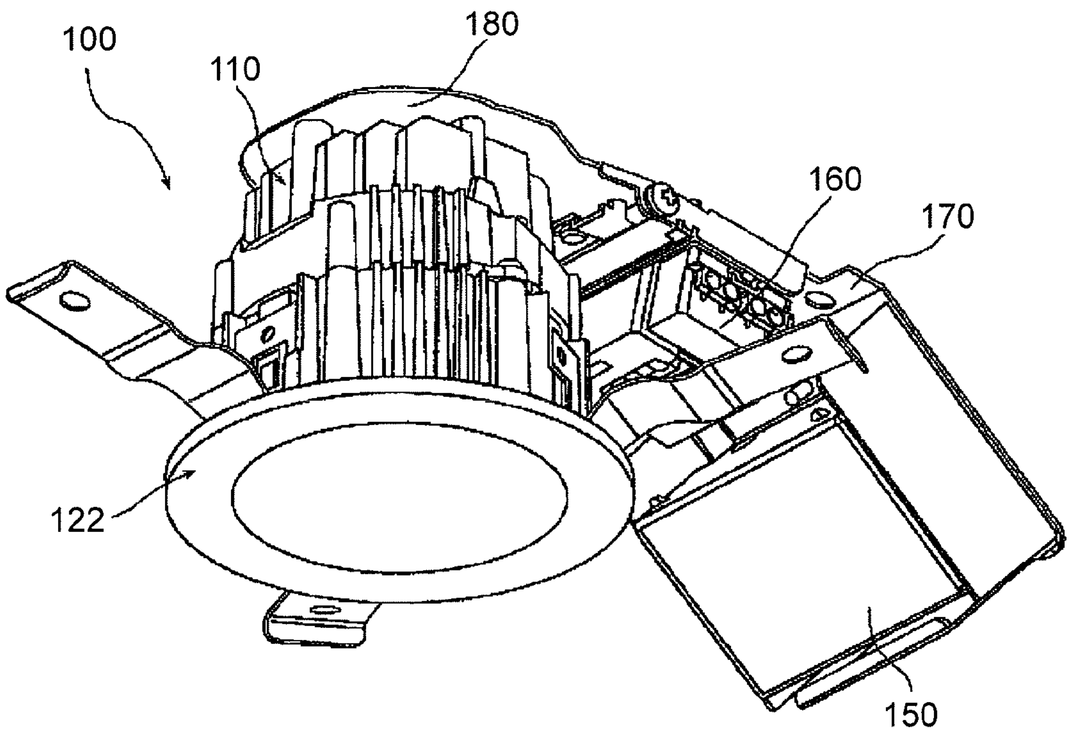


FIG. 15



LIGHT-EMITTING DEVICE AND LIGHTING APPARATUS USING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field relates to light-emitting devices, and lighting apparatuses in which light-emitting devices are used.

2. Background Art

Semiconductor light-emitting elements, such as light-emitting diode (LED), are broadly used in a range of apparatuses, such as for lighting and display, as highly-efficient and space-saving light sources.

For example, LEDs are used in alternative lighting apparatuses for conventional lamps, such as incandescent bulbs and fluorescent lamps, and ceiling-embedded lighting apparatuses that are embedded in the ceiling for emitting light downward, such as downlights and spotlights.

LEDs are unitized and built in a range of apparatuses in the form of LED modules (light-emitting devices). These LED modules include a COB (Chip On Substrate) light-emitting device in which multiple LED chips are directly mounted on a substrate, and an SMD (Surface Mount Device) light-emitting device in which multiple packaged SMD-type LED elements are mounted on a substrate.

SUMMARY OF THE INVENTION

A light-emitting device in exemplary embodiments includes a substrate, a first light-emitting element array having multiple first light-emitting elements mounted on the substrate and connected in series, and a second light-emitting element array having multiple second light-emitting elements mounted on the substrate and connected in series. Multiple wirings, including a first wiring, second wiring, third wiring, fourth wiring, and fifth wiring, are provided on the substrate. A first connector in which the first wiring and the third wiring are disposed adjacent to each other and also the first wiring and the fourth wiring are disposed adjacent to each other, and a second connector in which the second wiring and the fifth wiring are disposed adjacent to each other are also provided on the substrate. At least one first conductive member for electrically connecting at least the first wiring and the third wiring or the first wiring and the fourth wiring is provided in the first connector.

This structure achieves a light-emitting device that can support multiple different specifications, using a single type of substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a plan view of a light-emitting device in accordance with an exemplary embodiment of the present invention.

FIG. **1**B is a connecting diagram of a light-emitting element in the light-emitting device in FIG. **1**A.

FIG. **2** is a magnified sectional view of the light-emitting device taken along Line **2-2** in FIG. **1**A.

FIG. **3** is a plan view of the light-emitting device in FIG. **1**A when series connection is adopted.

FIG. **4**A is a schematic view illustrating a flow of current in the light-emitting device in FIG. **3**.

FIG. **4**B is an electric diagram of the light-emitting device in FIG. **3**.

FIG. **5** is a plan view of the light-emitting device in FIG. **1**A when parallel connection is adopted.

FIG. **6**A is a schematic view illustrating a flow of current in the light-emitting device in FIG. **5**.

FIG. **6**B is an electric diagram of the light-emitting device in FIG. **5**.

FIGS. **7** to **9** are plan views of processes in a method of manufacturing the light-emitting device in FIG. **1**A.

FIG. **10**A is a wiring pattern of another light-emitting device in accordance with the exemplary embodiment.

FIG. **10**B is a connecting diagram of a light-emitting element in the light-emitting device in FIG. **10**A.

FIG. **11**A is a schematic view illustrating a flow of current in the light-emitting device in FIG. **10**A when series connection is adopted.

FIG. **11**B is an electric diagram of the light-emitting device in FIG. **10**A when series connection is adopted.

FIG. **12**A is a schematic view illustrating a flow of current in the light-emitting device in FIG. **10**A when parallel connection is adopted.

FIG. **12**B is an electric circuit diagram of the light-emitting device in FIG. **10**A when parallel connection is adopted.

FIG. **13** is a wiring pattern of the light-emitting device in a modification of the light-emitting device in FIG. **10**A.

FIG. **14** is a sectional view of a lighting apparatus in an exemplary embodiment.

FIG. **15** is a perspective view of an appearance of the lighting apparatus in FIG. **14** and peripheral members connected to this lighting apparatus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

First, a disadvantage of a conventional light-emitting device is described before describing an exemplary embodiment. LED modules may be required to fulfill different allowable operating voltages depending on destinations (foreign countries), purposes of use, laws, and specifications including standards. Therefore, alignment of LEDs mounted on a substrate needs to be changed or a wiring pattern formed on the substrate needs to be changed depending on specifications. A price of the substrate, which is just one component in the LED module, thus becomes relatively high due to low volume production of a wide variety of substrates. This results in increasing the price of LED module.

The disclosure solves this disadvantage, and aims to offer a light-emitting device that can support multiple different specifications, using a single type of substrate.

To achieve this aim, the light-emitting device in exemplary embodiments includes a substrate, a first light-emitting element array mounted on the substrate and having multiple first light-emitting elements connected in series, and a second light-emitting element array mounted on the substrate and having multiple second light-emitting elements connected in series. Multiple wirings, including a first wiring, second wiring, third wiring, fourth wiring, and fifth wiring, are provided on the substrate. A first connector in which the first wiring and the third wiring are disposed adjacent to each other and also the first wiring and the fourth wiring are disposed adjacent to each other, and a second connector in which the second wiring and the fifth wiring are disposed adjacent to each other are also provided on the substrate. At least one first conductive member electrically connecting at least the first wiring and the third wiring or the first wiring and the fourth wiring is provided in the first connector.

The exemplary embodiments are described below with reference to drawings. The exemplary embodiments described herein are all preferred embodiments. It is thus apparent that values, shapes, materials, components, layout positions and connections of components, processes (steps), process sequences, and so on in the exemplary embodiments are therefore to be considered in all respects as illustrative and not restrictive.

Drawings are all schematic views, and thus they are not necessarily strictly-accurate illustrations. In each drawing, same reference marks are given to practically-same components to omit or simplify duplicate descriptions.

(Light-Emitting Device)

A structure of light-emitting device **1** in the exemplary embodiment is described with reference to FIGS. **1**A and **1**B and FIG. **2**. FIG. **1**A is a plan view of light-emitting device **1**. FIG. **1**B is a connecting diagram (circuit diagram) of LEDs **20** in light-emitting device **1**. FIG. **2** is a magnified sectional view of light-emitting device **1** taken along line **2-2** in FIG. **1**A.

As shown in FIG. **1**A, light-emitting device **1** is an LED module configured with multiple LEDs **20** (light-emitting elements). All LEDs **20** can be divided into first LEDs **21** and second LEDs **22**. Light-emitting device **1** includes substrate **10**, multiple first LEDs **21** and multiple second LEDs **22** mounted on substrate **10**, multiple wirings **30** formed on substrate **10**, and first connector **40**A and second connector **40**B in which some of multiple wirings **30** are disposed adjacent to each other for connection.

First LEDs **21** configure first LED array **21**A that is an array of light-emitting elements connected in series. Second LEDs **22** configure second LED array **22**A that is an array of light-emitting elements connected in series.

In light-emitting device **1**, first connector **40**A and second connector **40**B are provided to allow selection of 1) series connection or 2) parallel connection of first LEDs **21** and second LEDs **22** at the time of assembly. Each of first connector **40**A and second connector **40**B is configured with at least one first conductive member **411** for mutually connecting adjacent wirings **30** in multiple wirings **30**, and at least one connection pad **42**.

Multiple wirings **30** include first wiring **31**, second wiring **32**, third wiring **33**, fourth wiring **34**, and fifth wiring **35**. As shown in FIG. **1**A, third wiring **33** and fifth wiring **35** may be integrally formed.

In first connector **40**A, first wiring **31** and third wiring **33** are disposed adjacent to each other, and wiring **31** and fourth wiring **34** are disposed adjacent to each other. In second connector **40**B, second wiring **32** and fifth wiring **35** are connected adjacent to each other.

In first connector **40**A, at least first wiring **3** and third wiring **33** or first wiring **31** and fourth wiring **34** are electrically connected by at least one first conductive member **411**. FIG. **1**A is an example of connecting first wiring **31** and third wiring **33** by first conductive member **411**. First conductive member **411** is one of conductive member **41**.

Still more, light-emitting device **1** preferably includes multiple first sealing members **51** for sealing each of multiple arrays of linearly-aligned LEDs **20**, second sealing member **52** for sealing first conductive member **411**; wire **60** for applying current to LEDs **20**, and a pair of power supply terminals **71** and **72**.

Light-emitting device **1** is an LED module with COB structure in which LED chips are directly mounted on substrate **10**. Each component of light-emitting device **1** is detailed below.

[Substrate]

Substrate **10** is a substrate for mounting first LEDs **21** and second LEDs **22**. As substrate **10**, a ceramic substrate, resin substrate, metal-based substrate, or glass substrate can be typically used.

As a ceramic substrate, alumina substrate or aluminum nitride substrate can be used. As a resin substrate, a glass epoxy substrate or flexible substrate can be typically used. As a metal-based substrate, an aluminum alloy substrate on which an insulating film is formed on its surface, iron-alloy substrate, or copper-alloy substrate can be typically used.

As substrate **10**, a white substrate with high optical reflectance (e.g., optical reflectance of 90% or higher) is preferably used. The use of white substrate enables to reflect the light of LEDs **20** on the surface of substrate **10**. This improves the light extraction efficiency of light-emitting device **1**.

Light-emitting device **1** uses a ceramic substrate as substrate **10**. The ceramic substrate has high heat conductivity, compared to a resin substrate, and thus the heat of LEDs **20** can be efficiently dissipated. In addition, the ceramic substrate shows less time degradation and also has good heat resistance.

More specifically, for example, about 1-mm thick white polycrystal alumina substrate (polycrystal ceramic substrate) configured by sintering alumina particles can be used as substrate **10**.

Furthermore, for example, a rectangular substrate may be used as substrate **10**. Length of one side of substrate **10** may be, for example, 20 mm to 100 mm. For light-emitting device **1**, a rectangular substrate whose substrate size is 50 mm×70 mm is used as substrate **10**.

[LED]

First LEDs **21** and second LEDs **22** are connected in series in units of multiple pieces, respectively. In light-emitting device **1**, multiple first LEDs **21** connected in series configure first LED array **21**A, and multiple first LED arrays **21**A are connected in parallel to configure first LED group **21**G. In the same way, multiple second LEDs **22** connected in series configure second LED array **22**A, and multiple second LED arrays **22**A are connected in parallel to configure second LED group **22**G.

As an example, there are 240 first LEDs **21** and 240 second LEDs **22**. In 240 first LEDs **21**, twenty first LEDs **21** are connected in series to form one first LED array **21**A, and twelve first LED arrays **21**A are connected in parallel to form first LED group **21**G (twenty series-connections and twelve parallel-connections). In the same way in 240 second LEDs **22**, twenty second LEDs **22** connected in series form one second LED array **22**A, and twelve second LED arrays **22**A connected in parallel form second LED group **22**G (twenty series-connections and twelve parallel-connections).

LEDs **20** are also configured as multiple element arrays. In other words, all LEDs **20** are divided into multiple element arrays. Entire LEDs **20** are configured with twenty element arrays (divided element arrays **20**A) parallel to each other. In each of twenty divided element arrays **20**A, five or more but thirty-two or less LEDs **20** are linearly aligned. In each element array, multiple first LEDs **21** and multiple second LEDs **22** are linearly aligned, respectively. First sealing member **51** seals these first LEDs and second LEDs along the element arrays.

However, in light-emitting device **1**, LEDs **20** in one divided element array **20**A are not entirely connected in series. A series element array (first LED array **21**A or second LED array **22**A) configured with twenty LEDs **20** (first LEDs **21** or second LEDs **22**) connected in series may be entirely aligned in one divided element array **20**A, or may be aligned across multiple arrays using adjacent divided element array **20**A. In other words, at least first LEDs **21** or second LEDs **22** may be divided and aligned in multiple linear arrays.

When light-emitting device **1** is seen from the top, LEDs **20** are aligned such that entire multiple divided element arrays **20**A form a circle. In other words, the number of LEDs **20** mounted in each divided element array **20**A is adjusted such that entire twenty divided element arrays **20**A look round.

A mounting pitch of LEDs **20** (first LEDs **21** and second LEDs **22**) is, for example, from 0.7 mm or more to 3.0 mm or less. In light-emitting-device **1**, the pitch is 1.0 mm.

First LEDs **21** and second LEDs **22** can be electrically connected in series or parallel, or connected in combination of series and parallel, using wirings **30** and wires **60**, respectively.

First LEDs **21** and second LEDs **22** are an example of a semiconductor light-emitting element, and emit light by applying predetermined power. First LEDs **21** and second LEDs **22** are all bare chips that emit unicolor visible light. For example, they are blue LED chips that emit blue light when current is applied. As a blue LED chip, for example, gallium nitride semiconductor light-emitting element configured with InGaN material with the center wavelength of 440 nm to 470 nm can be used.

More specifically, as shown in FIG. **2**, second LED **22**, which is a blue LED chip, includes sapphire substrate **22**A and multiple nitride semiconductor layers **22**B configured with different compositions from each other that are laminated on sapphire substrate **22***a*.

Anode electrode (p electrode) **22***c* and cathode electrode (n electrode) **22***d* are provided at both ends of the top face of nitride semiconductor layers **22***b*. Wire-bonding part **22***e* is provided on anode electrode **22**C, and wire-bonding part **22***f* is provided on cathode electrode **22***d*. For example, in adjacent second LEDs **22**, anode electrode **22***c* of one second LED **22** and cathode electrode **22***d* of the other second LED **22** are connected by wire **60** via wire-bonding parts **22***e* and **22***f*. First LEDs **21** are also configured in the same way as that of second LEDs **22**.

As described above, adjacent LEDs **20** (first LEDs **21** or second LEDs **22**) are directly connected by wires **60** in light-emitting device **1**. In other words, adjacent LEDs **20** are wire-bonded in the chip-to-chip fashion. Alternatively, a land (wiring), which acts as a wire connector, may be provided on substrate **10**, and the land and LED **20** may be connected by wire-bonding, without adopting the chip-to-chip connection. However, the chip-to-chip connection can easily achieve higher integration of LEDs **20**.

In light-emitting device **1**, LEDs **20** are divided to form divided element arrays **20**A along a shorter side of substrate **10**. However, other arrangements are acceptable. For example, LEDs **20** may be divided to form divided element arrays along a longer side of substrate **10**. Still more, divided element arrays may be aligned in any directions.

The number of divided element arrays **20**A are not limited to twenty arrays. Divided element arrays **20**A also do not always have to form a circle. For example, entire divided element arrays **20**A may form rectangular. The number of LEDs **20** in one divided element array **20**A may be one or more, and this may be increased to the maximum number depending on the size of substrate **10**.

The forward voltage of LEDs **20** on substrate **10** is preferably the same, but the forward voltage of each of LEDs **20** may slightly vary. As long as the total forward voltage of the entire array of LEDs **20** is within a predetermined allowance, variations are acceptable. In other words, variations in the forward voltage of each of first LED arrays **21**A and the forward voltage of each of second LED arrays **22**A are acceptable as long as they are within the predetermined variation.

[Wiring]

Wirings **30** are formed for supplying power to LEDs **20** (first LEDs **21** and second LEDs **22**) mounted on substrate **10**. Wirings **30** are conductive members for running current to light LEDs **20**. For example, wirings **30** are made of metal. Wirings **30** are electrically connected to LEDs **20** (first LEDs **21** and second LEDs **22**), and are also electrically connected to a pair of power supply terminals **71** and **72**. This enables to supply predetermined current to LEDs **20** (first LEDs **21** and second LEDs **22**) via wirings **30**.

Wiring **30** is, for example, formed by etching or printing a metal film. Gold wiring, silver wiring, or copper wiring is typically used as a metal material for wiring **30**. Alternatively, wiring made by gold-plating on silver as a base metal may be used.

Wirings **30** are formed in predetermined patterns on the surface of substrate **10**. In light-emitting device **1**, wirings **30** include first wiring **31**, second wiring **32**, third wiring **33**, fourth wiring **34**, and fifth wiring **35**.

In first wiring **31**, its one end is connected to power supply terminal **71**, and its the other end is an open end. The open end of first wiring **31** is disposed between third wiring **33** and fourth wiring **34** in first connector **40**A. In other words, first wiring **31** is adjacent to third wiring **33** and fourth wiring **34**. In this description, the open end of wiring **30** refers to an end part of wiring **30** that is connected to nowhere.

Light-emitting device **1** has a pair of power supply terminals **71** and **72**. First wiring **31** is electrically connected to power supply terminal **71**, and second wiring **32** is electrically connected to the first end of first LED array **21**A and power supply terminal **72**. Still more, fifth wiring **35** is electrically connected to the first end of second LED array **22**A, and fourth wiring **34** is electrically connected to the second end of first LED array **21**A and the second end of second LED array **22**A. Third wiring **3** and fifth wiring **35** are integrally formed.

In second wiring **32**, its one end is connected to the first ends of multiple first LED arrays **21**A via wires **60**, and its other end is connected to power supply terminal **72**. More specifically, one end of second wiring **32** is branched to be connected to first LEDs **21** positioned at one furthest end (first end) of each of first LED arrays **21**A (twenty first LEDs **21** connected in series). A part of second wiring **32** is adjacent to fifth wiring **35** at least in second connector **40**B.

Fifth wiring **35** is connected to the first ends of second LED arrays **22**A configured with second LEDs **22** via wires **60**. Third wiring **33** and fifth wiring **35**, which are integrally formed, are open at both ends, and these wirings are branched in the middle to be connected to the first ends of second LED arrays **22**A. More specifically, a part of third wiring **33** and a part of fifth wiring **35** are branched to be connected to second LEDs **22** positioned at one furthest end (first end) of each of second LED arrays **22**A (twenty second LEDs **22** connected in series).

The open end of third wiring **33** is adjacent to first wiring **31** in first connector **40**A, and the open end of fifth wiring integrally formed with third wiring **33** is adjacent to second wiring **32** in second connector **40**B. More specifically, third wiring **33** and fifth wiring **35**, which are integrally formed, are disposed at the outermost part of wirings **30**, and they are extended to surround a mounting area (light-emitting area) of LEDs **20** from first connector **40**A to second connector **40**B.

In fourth wiring **34**, its one end is connected to the second ends of first LED arrays **21**A and the second ends of second LED arrays **22**A via wires **60**, and its the other end is an open end. The open end of fourth wiring **34** is adjacent to first wiring **31** in first connector **40**A.

One end of fourth wiring **34** is branched to be connected to first LEDs **21** positioned at the other outermost end (second end) of each of first LED arrays **21**A, and second LEDs **22** positioned at the other outermost end (second end) of each of second LED arrays **22**A.

In first connector **40**A and second connector **40**B, an interval between two adjacent wirings **30** is not particularly limited as long as it is a distance that can be at least wire-bonded.

Parts of wirings **30** exposed from first sealing member **51** and second sealing member **52** are preferably coated with an insulating film, such as a glass film (glass coating film) and insulating resin film (resin coating film). For example, as the resin film, a white resin material (white resist) with high reflectivity of about 98% can be used. To connect wiring **30** and first LED **21** or second LED **22**, using wire **60**, an opening is created in the insulating film to expose a part of wiring **30** as a wire connector (land). The insulating film is formed on the entire surface of substrate **10** except for this opening.

By coating the entire substrate **10** with the insulating film, such as white resist and glass coating film, a synthesized light emitted from first sealing member **51** can be reflected, and thus the light extraction efficiency of light-emitting device **1** can be improved. Still more, by coating wiring **30** with the insulating film, insulation (insulation strength voltage) of substrate **10** can be improved. Furthermore, oxidization of wiring **30** can be suppressed.

[Connector (Conductive Material, Connection Pad)]

First connector **40**A is configured to connect adjacent two wirings **30** in multiple wirings **30**, and includes at least one first conductive member **411** and at least one pair of connection pads (wire pads) **42**. Each of adjacent two wirings **30** (first wiring **31** and third wiring **33**, and first wiring **31** and fourth wiring **34**) in first connector **40**A has three pairs of connection pads **42**.

In the same way, second connector **40** is also configured to connect adjacent two wirings **30** in multiple wirings **30**, and has at least a pair of connection pads (wire pads) **42**. Adjacent second wiring **32** and fifth wiring **35** in second connector **40** have three pairs of connection pads **42**, respectively.

In first connector **40**A and second connector **40**B, conductive member **41** selectively connects two adjacent wirings in multiple wirings **30**, depending on series or parallel connection of first LED array **21**A and second LED array **22**A. More specifically, conductive member **41** connects at least one pair of connection pads **42** provided on adjacent two wirings **30**. This electrically and physically connects adjacent two wirings **30**.

For example, when first LED array **21**A and second LED array **22**A are connected in series, as shown in FIG. **1**A, at least one first conductive member **411** electrically connects first wiring **31** and third wiring **33** in first connector **40**A. First wiring **31** and fourth wiring **34** are not connected. Still more, second wiring **32** and third wiring **33** are not connected in second connector **40**B.

As described above, first LED array **21**A may be connected in parallel in multiple arrays (e.g., twelve parallel connections). In the same way, second LED array **22**A may be connected in parallel in a group of multiple arrays (e.g., twelve parallel-connections).

First conductive member **411** (conductive member **41**) is typically a thin conductive wire, such as a gold wire, and is stretched across at least one pair of protruding connection pads **42** facing each other. First conductive member **411** is sealed by second sealing member **52**, and is extended in the same direction as the longer direction of second sealing member **52**. Second sealing member seals at least one conductive member on connection pads **42**.

First conductive member **411** (conductive member **41**) preferably uses a material same as that of wires **60**, which is described later. This enables to form conductive members **41** and wires **60** using the same bonder (in the same process), and thus conductive member **41** can be formed without dropping the production efficiency. For example, gold wires with same electric capacitance can be used for conductive members **41** and wires **60**.

In first connector **40**A, the total number of first conductive members **411** for connecting adjacent wirings **30** is preferably the same or less number of parallel connections in each of first LED arrays **21**A and second LED arrays **22**A in first LED group **21**G and second LED group **22**G. The minimum number of parallel connections of LEDs **20** in light-emitting device **1** is twelve, which is the case when twelve first LED arrays **21**A connected in parallel are connected in series to twelve second LED arrays **22**A connected in parallel. Accordingly, the total number of first conductive members **411** for connecting adjacent two wirings **30** in first connector **40**A can be set to twelve or less. In light-emitting device **1**, adjacent wirings **30** are connected by nine first conductive members **411**. For example, the number of first conductive members **411** can be set to same as the above number of parallel connections or less by using a wire with capacity higher than capacity of current normally applied to LED chips for a wire of first conductive member **411**.

In other words, first LED array **21**A and second LED array **22**A are one of the same number of first LED arrays and second LED arrays, respectively. Multiple first LED arrays **21**A are connected in parallel, and multiple second LED arrays **22**A are connected in parallel. The total number of at least one first conductive member **411** in first connector **40**A can be set to the number of parallel connections or less.

In the same way, the total number of conductive members **41** can be set to the number of parallel connections or less when first wiring **31** and fourth wiring **34** are connected by at least one conductive member **41** in first connector **40**A, or when second wiring **32** and fifth wiring **35** are connected in second connector **40**B.

In addition, each of connection pads **42** is provided in each of adjacent two wirings **30** in first connector **40**A. More specifically, at least one pair of protruding connection pads **42** facing each other is provided between adjacent two wirings **30** (first wiring **31** and third wiring **33**, or first wiring **31** and fourth wiring **34**) and connected to wirings **30**. Each connection pad **42** can be typically configured with conductive material, such as metal including gold (gold pad).

In the same way in second connector **40**B, at least one pair of protruding connection pads **42** facing each other is provided between adjacent two wirings **30** (second wiring **32** and fifth wiring **35**).

In first connector **40**A and second connector **40**B, at least one pair of connection pads **42** is connected such that one connection pad **42** and the other connection pad **42** are connected by conductive member **41**. More specifically, a pair of connection pads **42** is wire-bonded by conductive member **41** configured with at least one wire. This electrically connects two wirings **30** facing each other.

At least three pairs of connection pads **42** are provided between each of adjacent two wirings **30** in first connector **40**A and second connector **40**B. In addition, in first connector **40**A, each of the pairs of connection pads **42** is connected by at least one first conductive member **411**. More specifically, each of the pairs of connection pads **42** is connected by three gold wires. By forming multiple conductive members **41** (wires) on one pair of connection pads **42**, the number of connection pads **42** can be reduced. An area of connection pads **42** on the substrate can thus be reduced. Furthermore, second sealing member **52** seals three gold wires (first conductive members **411**) in each pair of connection pads **42**.

A pair of connection pads **42** is connected by conductive member **41** to connect adjacent two wirings **30**. However, connection pads **42** may not be provided. In this case, adjacent two wirings **30** are directly connected by conductive member **41**.

In first connector **40**A, a bonding distance of first conductive members **411** (wires) can be set to, for example, from 0.5 mm or more to 3.0 mm or less. The bonding distance of first conductive member **41** is 0.8 mm. This is same for other conductive members **41** in first connector **40**A and second connector **40**B.

[First Sealing Member]

First sealing member **51** is formed on substrate **10** so as to cover first LEDs **21** and second LEDs **22**. By sealing first LEDs **21** and second LEDs **22** by first sealing member **51**, first LEDs **21** and second LEDs **22** can be protected. First sealing member **51** also seals wires **60**.

First sealing member **51** is linearly formed to integrally seal LEDs **20** in each divided element array **20**A. In other words, first sealing member **51** is formed for the number of divided element arrays **20**A of LEDs **20**. More specifically, twenty first sealing members **51** are formed in parallel to each other. In light-emitting device **1**, each of twenty first sealing members **51** is parallel to the shorter side of substrate **10**.

In this way, first sealing members **51** are linearly formed to cover all LEDs **20** in each divided element array **20**A along the direction (alignment direction) of LEDs **20**. Therefore, each of first sealing members **51** integrally seals each divided element array **20**A. In other words, first LEDs **21** of one first LED array **21**A and first LEDs **21** of another first LED array **21**A may be included in one divided element array **20**A. Still more, second LEDs **22** of one second LED array **22**A and second LEDs **22** of another second LED array **22**A may be included. Furthermore, first LEDs **21** of first LED array **21**A and second LEDs **22** of second LED array **22**A may be included. This means, even if LEDs **20** of different series element arrays (first LED array **21**A and second LED array **22**A) are included in one divided element array **20**A, LEDs **20** of different series element arrays are integrally sealed together. In other words, first LEDs **21** of one first LED array **21**A may be included in adjacent divided element arrays **20**A, or second LEDs **22** of one second LED array **22**A may be included in adjacent divided element arrays **20**A.

The length of each first sealing member **51** is adjusted to form a circle as a whole by twenty first sealing members **51**. However, first sealing members **51** do not have to form a circle as a whole. For example, first sealing members **51** may form rectangular as a whole.

First sealing member **51** is mainly configured with a translucent material. To convert light wavelengths of first LEDs **21** and second LEDs **22** to a predetermined wavelength, a wavelength converting member is mixed in first sealing member **51** (translucent material). In this case, first sealing member **51** contains phosphor as the wavelength converter, and functions as a wavelength converting member for converting wavelengths (colors) of lights emitted from first LEDs **21** and second LEDs **22**. For example, an insulating resin material that contains phosphor particles (phosphor-containing resin) is used for first sealing member **51**. Phosphor particles are excited by lights emitted from first LEDs **21** and second LEDs **22**, and discharge light with predetermined color (wavelength).

As a resin material configuring first sealing member **51**, for example, silicon resin can be used. In addition, an optical diffuser may be dispersed in first sealing member **51**. First sealing member **51** does not necessarily be formed by resin material. An organic material, such as fluorinated resin, or inorganic material, such as glass with low melting point and sol-gel glass, may be used for forming first sealing member **51**.

As phosphor particles mixed in first sealing member **51**, for example, YAG (yttrium aluminium garnet) yellow phosphor particles can be used for obtaining white light when first LEDs **21** and second LEDs **22** are blue LED chips that emit blue light. As a result, yellow phosphor particles contained in first sealing member **51** converts wavelength of a part of blue light emitted from first LEDs **21** and second LEDs **22** to yellow light. Then, the blue light not absorbed by yellow phosphor particles and the yellow light generated by converting wavelength by yellow phosphor particles are mixed in first sealing member **51**, and white light is discharged from first sealing member **51**. As an optical diffuser, silica particles are typically used.

In the above case, first sealing member **51** is phosphor-containing resin in which predetermined yellow phosphor particles are dispersed in silicon resin. The phosphor-containing resin is applied to the main face of substrate **10** using a dispenser, so as to integrally seal LEDs **20** in each divided element array **20**A. Then, the resin is cured to form first sealing member **51**.

This process is described in more details below. A dispensing nozzle of the dispenser is disposed facing a predetermined position on substrate **10**. Then, the dispensing nozzle is moved from one end to the other end of the divided element array while the sealing material (phosphor-containing resin before curing) is dispensed from the dispensing nozzle. Here, the sealing material is dispensed such that it covers LEDs **20** and also wires **60**.

First sealing member **51** applied and formed in this way is tubular, and its cross section perpendicular to the longer direction of first sealing member **51** is, for example, practically semi-circle.

A line pitch (center-to-center distance) of first sealing member **51** can be set to, for example, from 1.4 mm or more to 3.0 mm or less. The line pitch of first sealing member **51** is, for example, 1.8 mm. A sealing width (line width) of first sealing member **51** is, for example, 1.5 mm.

[Second Sealing Member]

On the other hand, second sealing member **52** is formed on substrate **10** to cover conductive members **41**, which are wires. By sealing conductive members **41** with second sealing member **52**, conductive members **41** can be protected.

Second sealing member **52** is linearly formed to cover conductive members **41**, connection pads **42**, and wirings **30** in first connector **40**A and second connector **40**B. Second sealing member **52** is formed on each of pairs of connection pads **42**.

For example, since three conductive members **41** are provided in one connection pad **42**, one second sealing member **52** is formed to integrally cover three conductive members **41**. In one first connector **40**A and second connector **40**B, three pairs of connection pads **42** are provided between adjacent two wirings **30**. Therefore, three second sealing members, in total, are formed between adjacent two wirings **30** of each pair of connection pads **42**. In other words, multiple conductive members **41** can be sealed in every pair of connection pads.

Second sealing member **52** can be configured with, for example, an insulating resin material. As second sealing member **52**, a material same as that for first sealing member **51** that seals LEDs **20** can be used. In light-emitting device **1**, the phosphor-containing resin, in which yellow phosphor particles are dispersed in silicon resin, is used for first sealing member **51**. Therefore, the same phosphor-containing resin is used for second sealing member **52**.

By configuring first sealing members **51** and second sealing members **52** using the same material, first sealing member **51** and second sealing member **52** can be formed in the same process. More specifically, first sealing member **51** and second sealing member **52** can be formed by consecutive application using the same dispensing nozzle. This achieves the line width (sealing width) of second sealing member **52** almost same as that of first sealing member **51**.

A line pitch (center-to-center distance) of second sealing member **52** can be set to, for example, from 1.4 mm or more to 3.0 mm or less. For example, the line pitch of second sealing member **52** is 2.8 mm, which is greater than that of first sealing member **51**. The line width of second sealing member **52** is 1.5 mm, which is same as that of first sealing member **51**.

Second sealing member **52** may be made of a material different from first sealing member **51**. Still more, all conductive members **41** (e.g., nine conductive members **41**) may be integrally sealed with one second sealing member **52** in first connector **40**A and second connector **40**B.

Light-emitting device **1** shows an example of forming second sealing member **52**. However, second sealing member **52** may not be formed. In this case, conductive members **41** and connection pads **42** remain exposed.

(Wire)

Wires **60** are a thin conductive wires for electrically connecting first LEDs **21** or second LEDs **22** and wirings **30**. For example, it is a gold wire. As described above, wire **60** directly connects adjacent two LEDs **20**. Wire **60** is preferably embedded in first sealing member **51** so as not to expose from first sealing member **51**.

In addition, wire **60** is extended in the direction same as the longer direction of first sealing member **51**. In other words, all wires **60** in first LED array **21**A (twenty first LEDs **21** connected in series) and second LED array **22**A (twenty second LEDs **22** connected in series) are linearly provided in a plan view.

By configuring conductive members **41** and wires **60** with the same material, they can be extended using the same bonder. This enables to wire-bond pairs of connection pads **42** in the same process as the wire-bonding process of LEDs **20**.

[Power Supply Terminal]

A pair of power supply terminals **71** and **72** is external connecting terminals (electrode terminals) for receiving predetermined power from outside light-emitting device **1** (an external power source). Light-emitting device **1** is connected to a single power source, and thus power is supplied to first LED arrays **21**A (first LEDs **21**) and second LED arrays **22**A (second LEDs **22**) from the same power source via the pair of power supply terminals **71** and **72**.

To emit light from LEDs **20** (first LEDs **21** and second LEDs **22**), power supply terminals **71** and **72** receive DC power from the power source, and supply received DC power to each LED **20** via wirings **30** and wires **60**.

For example, one power supply terminal **71** is a low-voltage power supply terminal, and the other power supply terminal **72** is a high-voltage power supply terminal.

Power supply terminals **71** and **72** may be a socket type. In this case, power supply terminals **71** and **72** are configured with a resin socket and conductive part (conductive pin) for receiving DC power. The conductive part is electrically connected to wirings **30** formed on substrate **10**. For example, one end of connector line (harness) whose the other end is typically connected to external power source is attached to the socket. This structure enables to receive power supply from the external power source via power supply terminals **71** and **72** via the connector line.

Other than the socket type, power supply terminals **71** and **72** may also be metal electrodes (metal terminals) configured typically with gold (Au) patterned in a rectangular shape.

[Relationship of LED Connection]

Next, connection of LEDs **20** is described with reference to FIGS. **3** to **6**B. FIG. **3** is a plan view of light-emitting device **1** adopting series connection. FIG. **4**A is a schematic view illustrating the flow of current in light-emitting device **1** in FIG. **3**. FIG. **4**B is an electric diagram of light-emitting device **1** in FIG. **3**. FIG. **5** is a plan view of light-emitting device **1** adopting parallel connection. FIG. **6**A is a schematic view illustrating the flow of current in light-emitting device **1** in FIG. **5**. FIG. **6**B is an electric diagram of light-emitting device **1** in FIG. **5**.

Next is described the case when first LED group **21**G configured with twelve first LED arrays **21** connected in parallel is connected in series to second LED group **22**G configured with twelve second LED arrays **22**A connected in parallel, with reference to FIGS. **3**, **4**A, and **4**B.

More specifically, as shown in FIG. **3**, LEDs **20** are aligned such that the alignment direction (chip direction) of first LEDs **21** in first LED array **21**A (twenty first LEDs **21** connected in series) and the alignment direction of second LEDs **22** in second LED array **22**A (twenty second LEDs **22** connected in series) are opposite when seen from the top. For example, each of LEDs **20** (first LEDs **21** and second LEDs **22**) form a rectangular shape when seen from the top. Their anode electrodes (+) are positioned toward one shorter sides of LEDs **20**, and their cathode electrodes (−) are positioned toward the other shorter sides of LEDs **20**. The opposite directions when seen from the top mean that positions of anode electrodes (+) and cathode electrodes (−) are opposite.

More specifically, in light-emitting device **1**, first LEDs **21** are aligned such that their anode electrodes (+) are positioned toward second wiring **32** (the side of power supply terminal **72**) in first LED array **21**A. On the other hand, second LEDs **22** are aligned such that their anode electrodes (+) are positioned toward fourth wiring **34** (the side of power supply terminal **71**) in second LED array **22**A.

Furthermore, a specific pair in adjacent two wirings **30** in first connector **40**A and second connector **40**B is connected by conductive member **41** to achieve series connection of first LED array **21**A and second LED array **22**A.

More specifically, in first connector **40**A, first wiring **31** and third wiring **33** are electrically connected by at least one first conductive member **411**, and first wiring **31** and fourth wiring **34** are not connected. In second connector **40**B, second wiring **32** and fifth wiring **35** are not connected.

As shown in FIGS. **4**A and **4**B, this achieves series connection of first LED array **21**A and second LED array **22**A. For example, when power circuit **90** for supplying rated current Ic to light-emitting device **1** is connected, current Ic runs in first LED group **21**B and second LED group **22**G. Then, forward current Ic/12 runs in each of LEDs **20** (first LEDs **21** and second LEDs **22**).

Next is described the case when first LED group **21**G configured with twelve first LED arrays **21**A connected in parallel is connected in parallel to second LED group **22**G configured with twelve first LED arrays **22**A connected in parallel, with reference to FIGS. **5**, **6**A, and **6**B.

More specifically, as shown in FIG. **5**, first LEDs **21** in first LED array **21**A and second LEDs **22** in first LED array **22**A may be aligned in the same alignment directions.

In light-emitting device **1**, first LEDs **21** are aligned such that their anode electrodes (+) are positioned toward second wiring **32** (the side of power supply terminal **72**) in first LED array **21**A, and second LEDs **22** are aligned such that their anode electrodes (+) are also positioned toward second wiring **32** (the side of power supply terminal **72**).

Furthermore, adjacent two wirings **30** in first connector **40**A and second connector **40**B are connected by conductive member **41** or not connected so as to achieve parallel connection of first LED array **21**A and second LED array **22**A.

More specifically, in first connector **40**A, first wiring **31** and fourth wiring **34** are electrically connected at least by one first conductive member **411**, and first wiring **31** and third wiring **33** are not connected. In second connector **40**B, second wiring **32** and fifth wiring **35** are electrically connected by at least one second conductive member **412**.

As shown in FIGS. **6**A and **6**B, this achieves parallel connection of first LED array **21**A and second LED array **22**A. For example, when power circuit **90** for supplying rated current Ic to light-emitting device **1** is connected, current Ic/2 runs in first LED group **21**G and second LED group **22**G. Then, shunt current of current Ic runs in each of LEDs **20** (first LEDs **21** and second LEDs **22**). Then, forward current Ic/24 runs in each of LEDs **20** (first LEDs **21** and second LEDs **22**).

The directions of first LEDs **21** and second LEDs **22** are changed between the case of series connection and the case of parallel connection of first LED array **21**A and second LED array **22**A. However, alignment is not limited. For example, when first LED array **21**A and second LED array **22**A are connected in series, directions of first LEDs **21** and second LEDs **22** are opposite in the above description, but they may be aligned in the same directions.

More specifically, positions of forming electrodes in first LEDs **21** and second LEDs **22** are determined so as to avoid linear alignment (alignment direction of LEDs **20**) of anode electrodes (+) and cathode electrodes (−) of first LEDs **21** and second LEDs **22**. Alternatively, directions of first LEDs **21** and second LEDs **22** are determined (e.g., oblique) so as to avoid linear alignment of wires **60** by oblique wire-bonding.

[Method of Manufacturing Light-Emitting Device]

Next, the method of manufacturing light-emitting device **1** is described with reference to FIGS. **7** to **9**. FIGS. **7** to **9** are plan views of each process of the method of manufacturing light-emitting device **1**.

As shown in FIG. **7**, as a mounting substrate, substrate **10** is prepared to form wirings **30** with predetermined pattern, power supply terminals **71** and **72**, and connection pads **42** in first connector **40**A and second connector **40**B. As required, an insulating film, such as white resist, may be formed on the surface of substrate **10**.

Next, depending on predetermined specifications of light-emitting device **1**, series connection or parallel connection is selected for first LED array **21**A and second LED array **22**A. Then, LEDs **20** are aligned to achieve selected connection. LEDs **20** or LEDs **20** and wirings **30** are then wire-bonded by wires **60**, and adjacent two wirings **30** in first connector **40**A and second connector **40**B are connected by conductive members **41**.

For example, when first LED array **21**A and second LED array **22**A are connected in series, LEDs **20** are mounted as shown in FIG. **8**. Then, LEDs **20** or LEDs **20** and wirings are wire-bonded by wires **60**, and first wiring **31** and third wiring **33** in first connector **40**A are wire-bonded by first conductive member **41** (wire). By forming first conductive members **411** using the same wire bonder as wires **60**, conductive member **41** can be formed without degrading productivity.

Next, as shown in FIG. **9**, linear first sealing member **51** is formed for sealing LEDs **20** (first LEDs **21** and second LEDs **22**) in units of divided element arrays **20**A and wires **60**.

Then, second sealing member **52** is formed across a pair of connection pads **42** in first connector **40**A and second connector **40**B. Here, by using the same material for first sealing member **51** and second sealing member **52**, first sealing member **51** and second sealing member **52** can be formed in the same process.

Alternatively, second sealing member **52** may be formed to seal only conductive member **41** and connection pad **42** connected to conductive member **41**. However, if second sealing member **52** is formed on all areas where conductive member **41** is possibly formed, there is no need to change areas to form second sealing member **52** depending on specifications for light-emitting device **1**. In other words, a common machine program can be used for applying second sealing member **52** by a dispenser.

[Effects]

Next, effects of light-emitting device **1** is described, including background to the disclosure.

Higher luminous flux has been demanded in LED modules for lighting. In particular, an LED module with high luminous flux is demanded in lighting apparatuses, such as for high ceiling, outdoor, and floodlight. More specifically, for example, an LED module for LED bulb with about input power of 4 to 5 W has been demanded. In addition, LED modules with high luminous flux of 100 W or more input power has been demanded.

To achieve such high luminous flux LED modules, the size of substrate for mounting LEDs may be enlarged to increase the number of LEDs mounted.

In this case, however, a problem of multi-shadow occurs if many LEDs (SMD-type LED elements) are placed on the substrate when the LED module has the SMD structure, in addition to the problem of enlarged LED module.

Therefore, high-density placement of many LEDs (LED chips) is considered, using COB-type LED module. In case of COB-type LED module, all LED chips mounted are integrally sealed by a sealing member (e.g., phosphor-containing resin), and thus the problem of multi-shadow that causes many shadows on the irradiated area does not occur.

However, if many LED chips are used, the chip mounting area becomes large, and thus an area to form the sealing member for integrally sealing LED chips (sealing area) also becomes large. As a result, a deformation level of the entire sealing member increases because thermal deformation at the center and periphery of the sealing member differs. This causes a problem of increased internal stress in the sealing member. In addition, thermal distribution becomes uneven at the center and periphery of the sealing member if the sealing area is enlarged. This also causes a problem of different internal stresses, depending on parts of the sealing member.

If many LED chips are used, the number of wires for applying current to LED chips also increases. If an influence of internal stress increases due to enlarged sealing area, as described above, a risk of disconnection of wires increases. As a result, reliability of LED module decreases.

On the other hand, allowable operating voltage of LED modules differs, as described above, depending on destinations, (foreign countries, etc.), purposes of use, and specifications based on their laws and standards. In this case, alignment of LEDs to be mounted need to be changed or wiring patterns need to be changed based on each specification. Low volume production of a wide variety of substrates, which is just one component in LED module, increases the price. The price of LED module thus also increases.

In particular, the unit price of high luminous flux LED module is high, and thus low volume production of a wide variety of LED modules (substrates) further increases the cost.

Also with respect to the LED module, low volume production of a wide variety of substrates requires increased manhour in order to assess reliability of the LED module. This may degrade reliability or accuracy of life prediction.

The subject matter is devised based on the above knowledge. The primary objective is to suppress cost increase due to difference in allowable voltages. In other words, multiple different specifications can be supported by enabling to select connection (series connection or parallel connection) of LEDs on a single-type of substrate at the time of production.

Still more, the secondary objective is to suppress the influence of sealing member even if the sealing area of sealing member is enlarged. The shape of sealing member is thus considered.

To achieve the primary objective, wirings **30** on substrate **10** are formed in multiple separate groups in advance in light-emitting device **1**. First LED array **21**A and second LED array **22**A are connected in series or parallel by connecting or not connecting these wirings **30** by conductive members **41**, depending on specifications for light-emitting device **1**. With this structure, series connection or parallel connection of first LED array **21**A and second LED array **22**A can be selected. Accordingly, multiple different specifications can be supported, using a single type of substrate **10**.

Still more, connection or non-connection of adjacent two wirings **30** can be selected in predetermined first connector **40**A and second connector **40**B. This structure facilitates selection of series connection or parallel connection of LEDs **20**.

To achieve the secondary objective, LEDs **20** mounted on substrate **10** are divided into divided element arrays, and LEDs **20** are sealed in units of divided element arrays **20**A by first sealing members **51**. In other words, multiple first sealing members **51** configure the sealing area.

With this structure, separate multiple first sealing members **51** are segmented and formed substantially perpendicular to the alignment direction of LEDs **20**. Stress concentration on first sealing members **51** in the substantially perpendicular direction can be eased to suppress internal stress. In addition, the internal stress of first sealing member **51** in each divided element array **20**A can be equalized.

In addition, in comparison of the sealing area when entire LEDs on the substrate are integrally sealed and the sealing area when LEDs **20** are sealed in units of divided element array **20**A, as in light-emitting device **1**, the sealing area for separately sealing each divided element array **20**A is smaller. Deformation of first sealing member **51** can thus be suppressed, compared to the case of integrally sealing all LEDs **20**. Accordingly, the internal stress of first sealing member **51** can be eased.

By dividing sealing member to multiple groups in this way, the internal stress of first sealing member **51** can be suppressed and equalized. A risk of disconnection of wires **60** can thus be reduced. This enables to achieve a highly-reliable light-emitting device.

Still more, thermal deformation of first sealing member **51** in the substantially perpendicular direction can be reduced by dividing the sealing member to multiple first sealing members **51**. Therefore, thermal deformation of multiple first sealing members **51** as a whole can be reduced. In addition, heat release can be improved, compared to the case of integrally sealing all LEDs **20**, by dividing the sealing area to multiple first sealing members **51**. This further reduces thermal deformation of the sealing area (first sealing members **51**). Better heat release also suppresses reduction of light-emission efficiency of LEDs **20**. As a result, the light-emitting device suitable for higher luminous flux can be easily achieved.

If all LEDs **20** are integrally sealed by one sealing member, the surface of sealing member becomes flat and causes total reflection. This degrades the light extraction efficiency. However, by dividing the sealing area into multiple first sealing members **51**, as in light-emitting device **1**, the surface of each first sealing member **51** can be curved. Accordingly, the optical transmission efficiency can be improved, compared to the case of integrally sealing all LEDs **20**.

Still more, LEDs **20** are divided into multiple divided element arrays **20**A, and first sealing member **51** is formed on each divided element array **20**A. This makes a light-emitting part (first sealing member **51**) same in all arrays. Therefore, the entire light-emitting area can be evaluated just by evaluating one array of light-emitting part (first sealing member **51**). This enables to efficiently predict service life, and also suppress degradation of accuracy of life prediction. The reliability can also be easily determined.

Even if the sealing area is configured with multiple first sealing members **51**, a problem of multi-shadow does not occur.

As described above, light-emitting device **1** and substrate **10**, on which wirings **30** are formed, enable to select series connection or parallel connection. The sealing area is divided into multiple areas. This achieves a highly-reliable light-emitting device with high light extraction efficiency even if the number of LEDs is increased to achieve higher luminous flux.

Still more, same material as first sealing member **1** for sealing LEDs **20** (first LEDs **21** and second LEDs **22**) is used for second sealing member **52** for sealing conductive members **41**.

This enables to seal conductive members **41** in the same way as that for sealing LEDs **20** (LED chips). Therefore, second sealing member **52** can be easily formed, and the reliability can also be verified in a simplified manner.

Still more, the width of first sealing member **51** and the width of second sealing member **52** are almost the same. In other words, a cross-sectional shape (cross-section area) of first sealing member **51** and a cross-sectional shape (cross-section area) of second sealing member **52** are almost identical. Therefore, each pair of connection pads **42** is sealed with second sealing member **52** instead of integrally sealing multiple pairs (e.g. three pairs) of connection pads **42** with second sealing member **52** in first connector **40**A and second connector **40**B.

This enables to unify internal stress in the entire sealing members including first sealing member **51** and second sealing member **52**. In addition, since the internal stresses of first sealing member **51** (light-emitting area) and second sealing member **52** (wiring connection area) become the same, risks of disconnection of wires **60** and conductive members **41** (wires) also become the same. Accordingly, a highly-reliable light-emitting device can be achieved.

Still more, in first connector **40**A and second connector **40**B, the total number of conductive members **41** for mutually connecting adjacent wirings **30** is set to not greater than the number of minimum parallel connections of LEDs **20**.

If the mounting number of LEDs **20** increases, due to higher luminous flux of the light-emitting device, the number of parallel connections of LEDs **20** also increases and current applied to light-emitting device **1** also increases. Therefore, the total number of conductive members **41** is preferably set to not greater than the minimum parallel connections of LEDs **20**.

Still more, the connection wiring area (second sealing member **52**) is preferably away from light-emitting area (first sealing member **51**).

If the connection wiring area is close to the light-emitting area, light enters again from the light-emitting area (first sealing member **51**) to connection wiring area (second sealing member **52**). This degrades light emission efficiency and causes color unevenness in the irradiated area. Contrarily, by setting the connection wiring area away from the light-emitting area, degradation of light emission efficiency or generation of color unevenness in the irradiated area can be suppressed.

Next is described light-emitting device **2**, which is another light-emitting device in the exemplary embodiment, with reference to FIGS. **10**A to **12**B. FIG. **10**A illustrates a wiring pattern of light-emitting device **2**. FIG. **10**B is a connecting diagram (circuit diagram) of LEDs **20** in light-emitting device **2**.

Light-emitting device **2** further includes multiple third LEDs **23** in LEDs **20**, and sixth wirings **36** in multiple wirings **30**, relative to light-emitting device **1**.

Same as light-emitting device **1**, LEDs **20** on substrate **10** are configured with multiple element arrays. In other words, all LEDs **20**, including third LEDs **23**, are divided into element arrays.

Third LEDs **23** mounted on substrate **10** are connected in series in units of multiple LEDs. For example, in the same way as first LED arrays **21**A and second LED arrays **22**A, twenty third LEDs **23** connected in series form third LED array **23**A, and twelve third LED arrays **23**A are connected in parallel to configure third LED group **23**G.

As third LEDs **23**, LEDs **20** can be used, same as first LEDs **21** and second LEDs **22**. Also same as first LEDs **21** and second LEDs **22**, third LEDs **23** are configured with multiple divided element arrays **20**A. First sealing member **51** is formed on each divided element array **20**A.

Also in light-emitting device **2**, wirings **30** include first wiring **31**, second wiring **32**, third wiring **33**, fourth wiring **34**, fifth wiring **35**, and sixth wiring **36** that are formed separate from each other. Pattern shapes of first wiring **31**, second wiring **32**, and fourth wiring **34** in light-emitting device **2** are the same as those in light-emitting device **1**.

In fifth wiring **35**, its one end is electrically connected to the first end of second LED array **22**A via wire **60** (not illustrated), and its other end is an open end. The open end of fifth wiring **35** is disposed between second wiring **32** and sixth wiring **36** in second connector **40**B. In other words, fifth wiring **35** is adjacent to second wiring **32** and sixth wiring **36**.

In sixth wiring **36**, its one end is electrically connected to the first end of third LED array **23**A via wire **60** (not illustrated), and its other end is an open end. The open end of sixth wiring **36** is adjacent to fifth wiring **35** in second connector **40**B.

In third wiring **33**, its one end is electrically connected to the second end of third LED array **23**A via wire **60** (not illustrated), and its other end is an open end. The open end of third wiring **33** is adjacent to first wiring **31** in first connector **40**A.

In second connector **40**B, multiple connection pads **42** are provided also for sixth wiring **36**, same as other wirings. Sixth wiring **36** can be connected to adjacent fifth wiring **35** by conductive member **41**.

Light-emitting method **2** can be manufactured using the same method as that of light-emitting device **1**.

Next, connections of LEDs **20** in light-emitting device **2** are described with reference to FIGS. **11**A to **12**B. FIG. **11**A is a schematic view illustrating the flow of current in light-emitting device **2** in the case of series connection. FIG. **11**B is an electric diagram of light-emitting device **2** in FIG. **11**A. FIG. **12**A is a schematic view of the flow of current in light-emitting device **2** in the case of parallel connection. FIG. **12**B is an electric diagram of light-emitting device **2** in FIG. **12**A.

The case of connecting first LED group **21**G, second LED group **22**G, and third LED group **23**G in series is described with reference to FIGS. **11**A and **11**B.

More specifically, as shown in FIG. **11**A, first LEDs **21** of first LED array **21**A are aligned in the direction opposite to second LEDs **22** of second LED array **22**A when seen from the top. In addition, third LEDs **23** of third LED array **23**A are aligned in the same direction as first LEDs **21**.

In first LED array **21**A and third LED array **23**A, first LEDs **21** and third LEDs **23** are disposed such that their anode electrodes (+) are positioned toward second wiring **32** (the side of power supply terminal **72**). On the other hand, in second LED array **22**A, second LEDs **22** are disposed such that their anode electrodes (+) are positioned toward fourth wiring **34** (the side of power supply terminal **71**).

Furthermore, only specific pairs of adjacent wirings **30** in first connector **40**A and second connector **40**B are connected by conductive member **41** so that first LED array **21**A, second LED array **22**A, and third LED array **23**A are connected in series.

In first connector **40**A, first wiring **31** and third wiring **33** are electrically connected at least by one first conductive member **411**, and first wiring **31** and fourth wiring **34** are not connected. In addition, in second connector **40**B, second wiring **32** and fifth wiring **35** are not connected, and fifth wiring **35** and sixth wiring **36** are electrically connected at least by one second conductive member **412**.

As shown in FIGS. **11**A and **11**B, this enables to connect first LED group **21**G, second LED group **22**G, and third LED group **23**G in series. For example, when power circuit **90** for supplying constant current Ic to light-emitting device **2** is connected, forward current Ic/12 runs in each of LEDs **20** in first LED group **21**G, second LED group **22**G, and third LED group **23**G (first LEDs **21**, second LEDs **22**, and third LEDs **23**).

Next is described the case of connecting first LED group **21**G, second LED group **22**G, and third LED group **23**G in parallel, with reference to FIGS. **12**A and **12**B.

More specifically, as shown in FIG. **12**A, first LEDs **21** of first LED array **21**A, second LEDs **22** of second LED array **22**A, and third LEDs **23** of third LED array **23**A are all disposed in the same direction when seen from the top.

In first LED array **21**A, first LEDs **21** are disposed such that their anode electrodes (+) are positioned toward second wiring **32** (the side of power supply terminal **72**). Still more, in second LED array **22**A, second LEDs **22** are also disposed such that their anode electrodes (+) are positioned toward second wiring **32** (the side of power supply terminal **72**). Still more, in third LED array **23**A, third LEDs **23** are also disposed such that their anode electrodes (+) are positioned to the side of second wiring **32** (the side of power supply terminal **72**).

Furthermore, only specific pairs of adjacent wirings **30** in first connector **40**A and second connector **40**B are connected by conductive member **41** so that first LED array **21**A, second LED array **22**A, and third LED array **23**A are connected in parallel.

In first connector **40**A, first wiring **31** and third wiring **33** are electrically connected by at least one first conductive member **411**, and first wiring **31** and fourth wiring **34** are electrically connected by at least one second conductive member **412**. In second connector **40**B, second wiring **32** and fifth wiring **35** are electrically connected by at least one third conductive member **413**, and fifth wiring **35** and sixth wiring **36** are electrically connected by at least one fourth conductive member **414**.

As shown in FIGS. **12**A and **12**B, this enables to connect first LED group **21**G, second LED group **22**G, and third LED group **230** in parallel. For example, when power circuit **90** for supplying constant current Ic to light-emitting device **2** is connected, current Ic/3 runs in first LED group **21**G, second LED group **220**, and third LED group **23**G. And, shunt current of current Ic/3 runs in LEDs **20** (first LEDs **21**, second LEDs **22**, and third LEDs **23**). More specifically, forward current Ic/36 runs in each of first LEDs **21**, second LEDs **22**, and third LEDs **23**.

In the same way as light-emitting device **1**, first LEDs **21**, second LEDs **22**, and third LEDs **23** may be disposed in the same direction even if first LED array **21**A, second LED array **22**A, and third LED array **23**A are connected in series.

As described above, same as light-emitting device **1**, light-emitting device **2** enables to select series connection or parallel connection of LEDs **20** (first LEDs **21**, second LEDs **22**, and third LEDs **23**). Accordingly, a single type of substrate **10** can support multiple different specifications.

Still more, also in light-emitting device **2**, the sealing area consists of multiple first sealing members **51**. Therefore, same as light-emitting device **1**, an effect of suppressing internal stress can be obtained. A risk of disconnection of wires **60** can also be reduced. Accordingly, a highly-reliable light-emitting device can be achieved.

Still more, light-emitting device **2** may have a pattern shown in FIG. **13** for wirings **30**. FIG. **13** illustrates a wiring pattern of light-emitting device **2**A, which is modification of light-emitting device **2**.

In light-emitting device **2**A, first LED array **21**A having multiple first LEDs **21** connected in series is provided on substrate **10**. In addition, second LED array **22**A having multiple second LEDs **22** connected in series is provided. Furthermore, third LED array **23**A having multiple third LEDs **23** connected in series is provided. Multiple wirings are provided on substrate **10**, including first wiring **31**, second wiring **32**, third wiring **33** electrically connected to first wiring **31**, fourth wiring **34**, fifth wiring **35**, and sixth wiring **36** electrically connected to fifth wiring. Still more, on substrate **10**, first connector **40**A in which first wiring **31** and fourth wiring **34** are disposed adjacent to each other, second connector **40**B in which first connector **40**A, second wiring **32**, and fifth wiring **35** are disposed adjacent to each other, and a pair of power supply terminals **71** and **72** is provided. First wiring **31** is electrically connected to power supply terminal **71**, and second wiring **32** is electrically connected to the first end of first LED array **21**A and power supply terminal **72**. Fourth wiring **34** is electrically connected to the second end of first LED array **21**A and the second end of second LED array **22**A. The first end of third LED array **23**A is electrically connected to sixth wiring **36**, and the second end of third LED array **23**A is electrically connected to third wiring **33**.

In other words, as shown in FIG. **13**, first wiring **31** and third wiring **33** are a single wiring without being separated in light-emitting device **2**A. Fifth wiring **35** and sixth wiring **36** are also a single wiring without being separated.

Also with this structure, connections same as light-emitting device **2** shown in FIG. **10** are achieved by connecting or not connecting connection pads **42** by conductive member **41** in first connector **40**A and second connector **40**B.

More specifically, in FIG. **13**, first LED array **21**A, second LED array **22**A, and third LED array **23**A can be connected in series, same as FIG. **11**B, by not connecting connection pads **42** (not providing conductive member **41**) in first connector **40**A and second connector **40**B.

On the other hand, first wiring **31** and fourth wiring **34** are electrically connected by at least one first conductive member **411** on at least a pair of connection pads **42** in first connector **40**A. In the same way, at least a pair of connection pads **42** in second connector **40**B is connected by at least one second conductive member **412**. This enables to connect first LED array **21**A, second LED array **22**A, and third LED array **23**A in parallel, same as FIG. **12**B.

Accordingly, light-emitting device **2**A in FIG. **13** can simplify wirings **30** (metal wirings), compared to light-emitting device **2** in FIG. **10**.

(Lighting Apparatus)

Next, lighting apparatus **100** in the exemplary embodiment is described with reference to FIGS. **14** and **15**. FIG. **14** is a sectional view of lighting apparatus **100** (ceiling-embedded type). FIG. **15** is a perspective view of an appearance of lighting apparatus **100** to be connected to peripheral members (lighting device and terminal base).

Lighting apparatus **100** is, for example, an embedded lighting apparatus, such as a downlight, for irradiating light downward (corridor, wall, etc.) by being embedded in a ceiling typically of a house. Lighting apparatus **100** includes light-emitting device **1** that is an LED light source, a substantially-tubular apparatus body with bottom formed by joining base **110** and frame **120**, and reflector **130** and translucent panel **140** disposed in this apparatus body. Light-emitting device **2** or **2**A may be used instead of light-emitting device **1**.

Base **110** is an attachment base for receiving light-emitting device **1**. It is also a heat sink for releasing heat generated in light-emitting device **1**. Base **110** is typically formed by metal in a substantially cylindrical shape. For example, aluminum die-cast can be used for lighting apparatus **100**.

Multiple heat-release fins **111** protruding upward are provided at a constant interval in one direction on an upper part of base **110**. This enables to efficiently dissipate heat generated in light-emitting device **1**.

Frame **120** includes substantially tubular cone **121** having a reflective face on its inner face, and frame body **122** for attaching cone **121**. Cone **121** is formed using metal. For example, cone **12** is made by drawing or pressing aluminum alloy. Frame body **122** is formed of a rigid resin material or metal material. Frame body **120** is fixed by attaching frame body **122** to base **110**.

Reflector **130** is an annular-frame (funnel shape) having a reflective inner-face. Reflector **130** can be formed using metal, such as aluminum. Reflector **130** may not be metal. It may be formed with a rigid white resin material.

Translucent panel **140** is a flat plate disposed between reflector **130** and frame body **120**, and is attached to reflector **130**. Translucent panel **140** can be formed in a disk shape using a transparent resin material, such as acryl and polycarbonate.

However, translucent panel **140** is not necessarily provided. If translucent panel **140** is not provided, luminous flux of a lighting apparatus can be improved.

As shown in FIG. **15**, lighting device **150** for supplying lighting power to light-emitting device **1** and terminal base **150** for relaying AC power from a commercial power source to lighting device **160** are connected to lighting apparatus **100**.

Lighting device **150** and terminal base **160** are attached and fixed to attachment plate **170** provided separately from the apparatus body. Attachment plate **170** is formed by bending a rectangular metal sheet. Lighting device **150** is attached and fixed to the bottom face at one end in the longer direction, and terminal base **160** is attached and fixed to the bottom face at the other end. Attachment plate **170** is mutually connected to top plate **180** attached and fixed onto the top of base **110** of the apparatus body.

As described above, lighting apparatus **100** can be achieved by employing light-emitting device **1**, **2**, or **2**A.

(Others)

As described above, light-emitting devices **1**, **2**, and **2**A, lighting apparatus **100**, and substrate **10** on which wirings **30** are provided are described with reference to exemplary embodiments. However, the subject matter is not limited to these exemplary embodiments.

For example, blue LED chips and yellow phosphor are combined in light-emitting devices **1**, **2**, **2**A (LED modules). However, the combination is not limited. For example, phosphor-containing resin that contains red phosphor and green phosphor may be combined with blue LEDs. Alternatively, ultraviolet LED chips discharging ultraviolet light that has a wavelength shorter than blue LED chips may be combined with blue phosphor particles, green phosphor particles, and red phosphor particles that discharge blue light, red light, and green light by being excited mainly by ultraviolet light.

Still more, in light-emitting devices **1**, **2**, and **2**A, an LED is given as an example of a light-emitting element. A semiconductor light-emitting element, such as a semiconductor laser, EL elements, such as organic EL (Electric Luminescence) and inorganic EL, and other solid light-emitting elements may also be used.

Furthermore, embodiments achieved by a range of modifications that may come up to each exemplary embodiment and embodiments achieved by arbitrary combining components and functions of each exemplary embodiment without departing from the spirit of the disclosure are intended to be embraced therein.

The light-emitting device in the disclosure includes the substrate, first LEDs and second LEDs mounted on the substrate, wirings separately formed on the substrate, and conductive members for connecting adjacent two wirings in multiple wirings. First LEDs and second LEDs can be connected in series or parallel, or in combination of series and parallel. This enables to support multiple different specifications, using a single type of substrate.

What is claimed is:

1. A light-emitting device comprising:
a substrate;
a first light-emitting element array mounted on the substrate and having a plurality of first light-emitting elements connected in series;
a second light-emitting element array mounted on the substrate and having a plurality of second light-emitting elements connected in series;
a first sealing member for sealing the plurality of first light-emitting elements and the plurality of second light-emitting elements;
a plurality of wirings provided on the substrate and including a first wiring, a second wiring, a third wiring, a fourth wiring, and a fifth wiring;
a first connector in which the first wiring and the third wiring are disposed adjacent to each other, and the first wiring and the fourth wiring are disposed adjacent to each other;
a second connector in which the second wiring and the fifth wiring are disposed adjacent to each other; and
at least one first conductive member for electrically connecting the first wiring and at least one of the third wiring and the fourth wiring in the first connector.

2. The light-emitting device of claim **1**,
wherein
the first light-emitting element array and the second light-emitting element array are one of a plurality of first light-emitting element arrays and one of a plurality of second light-emitting element arrays, respectively, having a same number of arrays,
the plurality of first light-emitting element arrays are connected in parallel, and the plurality of second light-emitting element arrays are connected in parallel, and
a total number of the at least one first conductive member in the first connector is not greater than the same number of arrays.

3. The light-emitting device of claim **1**,
wherein
the at least one first conductive member is a wire.

4. The light-emitting device of claim **1**,
wherein
power is supplied from a same power source to the first light-emitting elements and the second light-emitting elements.

5. A lighting apparatus comprising:
the light-emitting device of claim **1**; and
an attachment base for receiving the light-emitting device.

6. The light-emitting device of claim **1**,
wherein
each of the plurality of first light-emitting elements and the plurality of second light-emitting elements configures a linear element array, and
the first sealing member seals the plurality of first light-emitting elements and the plurality of second light-emitting elements along the element array.

7. The light-emitting device of claim **6**,
wherein
at least one of the plurality of first light-emitting elements and the plurality of second light-emitting elements is aligned in a plurality of linear arrays.

8. The light-emitting device of claim **1**,
wherein
at least one pair of connection pads is provided between each of the first wiring and the third wiring, and the first wiring and the fourth wiring in the first connector,
the at least one first conductive member connects the at least one pair of connection pads together, and
a second sealing member seals the at least one first conductive member.

9. The light-emitting device of claim **8**,
wherein
the at least one pair of connection pads protrudes, facing each other, in the first connector.

10. The light-emitting device of claim **8**,
wherein
the second sealing member seals the at least one first conductive member for the at least each pair of connection pads.

11. The light-emitting device of claim **8**,
wherein
the first sealing member and the second sealing member are formed using a same material.

12. The light-emitting device of claim **1**, further comprising:
a pair of power supply terminals,
wherein
the first wiring is electrically connected to one of the pair of power supply feeding terminals,

the second wiring is electrically connected to a first end of the first light-emitting element array and an other of the pair of power supply terminals,

the fifth wiring is electrically connected to a first end of the second light-emitting element array, and

the fourth wiring is electrically connected to a second end of the first light-emitting element array and a second end of the second light-emitting element array.

13. The light-emitting device of claim **12**,

wherein

the at least one first conductive member electrically connects the first wiring and the third wiring in the first connector, and

the third wiring and the fifth wiring are electrically connected.

14. The light-emitting device of claim **12**, further comprising:

a second conductive member for electrically connecting the second wiring and the fifth wiring in the second connector,

wherein

the at least one first conductive member electrically connects the first wiring and the fourth wiring in the first connector, and

the third wiring and the fifth wiring are electrically connected.

15. The light-emitting device of claim **12**, further comprising:

a third light-emitting element array mounted on the substrate and being configured with a plurality of third light-emitting elements connected in series,

wherein

the plurality of wirings further include a sixth wiring,

the sixth wiring is disposed adjacent to the fifth wiring in the second connector,

a first end of the third light-emitting element array is electrically connected to the sixth wiring, and

a second end of the third light-emitting element array is electrically connected to the third wiring.

16. The light-emitting device of claim **15**, further comprising:

at least one second conductive member for electrically connecting the fifth wiring and the sixth wiring in the second connector,

wherein

the at least one first conductive member electrically connects the first wiring and the third wiring in the first connector.

17. The light-emitting device of claim **15**, further comprising:

at least one second conductive member for electrically connecting the first wiring and the fourth wiring in the first connector;

at least one third conductive member for electrically connecting the second wiring and the fifth wiring in the second connector; and

at least one fourth conductive member for electrically connecting the fifth wiring and the sixth wiring in the second connector,

wherein

the at least one first conductive member electrically connects the first wiring and the third wiring in the first connector.

18. A light-emitting device comprising:

a substrate;

a first light-emitting element array mounted on the substrate and having a plurality of first light-emitting elements connected in series;

a second light-emitting element array mounted on the substrate and having a plurality of second light-emitting elements connected in series;

a third light-emitting element array mounted on the substrate and having a plurality of third light-emitting elements connected in series;

a plurality of wirings provided on the substrate and including a first wiring, a second wiring, a third wiring electrically connected to the first wiring, a fourth wiring, a fifth wiring, and a sixth wiring electrically connected to the fifth wiring;

a first connector in which the first wiring and the fourth wiring are disposed adjacent to each other;

a second connector in which the second wiring and the fifth wiring are disposed adjacent to each other; and

a pair of power supply terminals,

wherein

the first wiring is electrically connected to one of the pair of power supply terminals,

the second wiring is electrically connected to a first end of the first light-emitting element array and the other one of the pair of power supply terminals,

the fourth wiring is electrically connected to a second end of the first light-emitting element array and a second end of the second light-emitting element array, and

a first end of the third light-emitting element array is electrically connected to the sixth wiring, and a second end of the third light-emitting element array is electrically connected to the third wiring.

19. The light-emitting device of claim **18**, further comprising:

at least one first conductive member for electrically connecting the first wiring and the fourth wiring in the first connector; and

a second conductive member for electrically connecting the second wiring and the fifth wiring in the second connector.

* * * * *